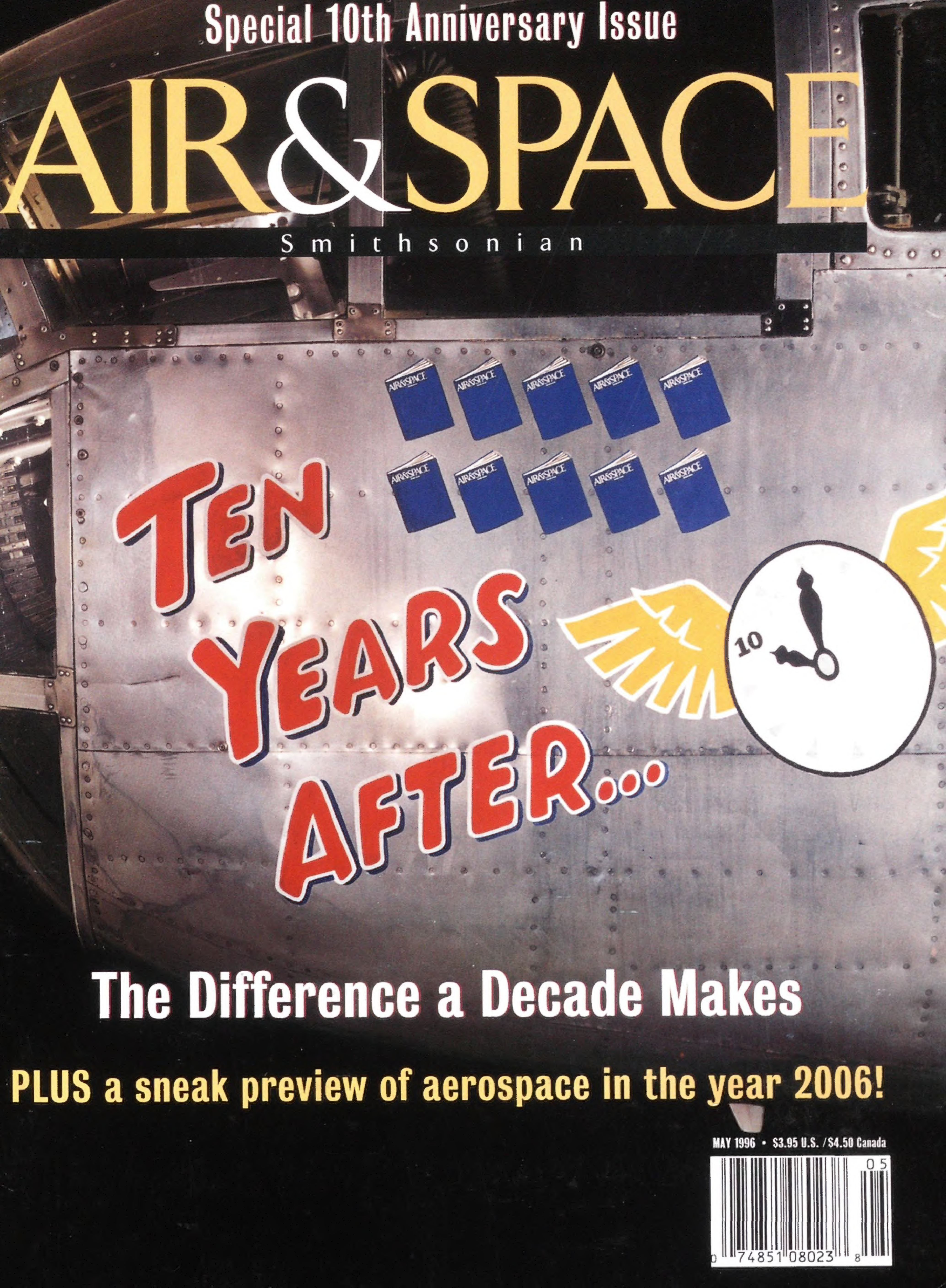
Special 10th Anniversary Issue

AIR&SPACE

Smithsonian



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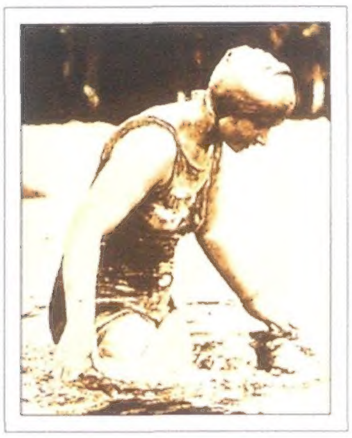
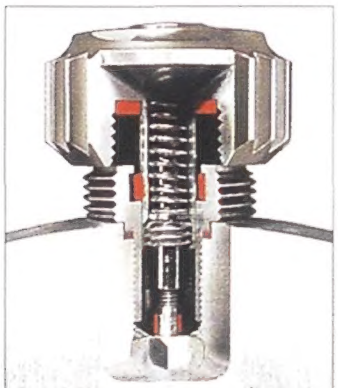
A History of

The history of the Rolex Oyster has been closely allied not only with watchmaking achievements but also with some of history's greatest human accomplishments. Wherever and whenever people have tested the best in themselves, pushed the edge of the envelope, the limits of speed and endurance, Rolex is likely to have been with them. And what makes Rolex so remarkably dependable today is that just as those who have constantly sought to improve their performance, so have we.

1914: Just ten years after the founding of the company, Rolex is certified as the first wristwatch to outperform the pocketwatch by the Kew Observatory.



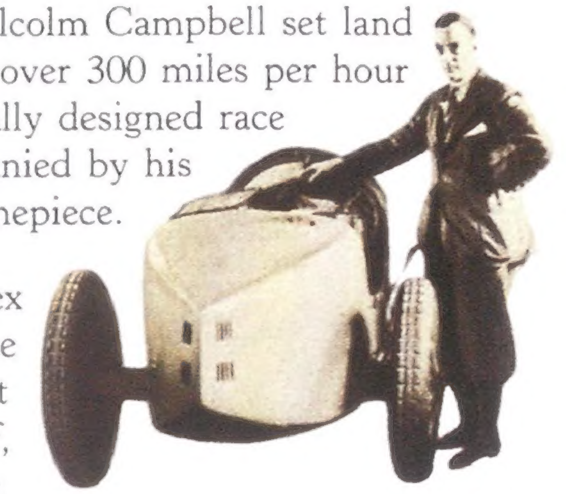
1926: Rolex invented the rugged Oyster case and the screw-down winding crown, developed on the same principle as the submarine hatch. The reliability of the Oyster was proven when, in 1927, Mercedes Gleitze swam the English Channel in 15 hours and 15 minutes. Her Rolex Oyster successfully timed her swim.



The Twinlock winding crown.

The screw-down winding crown that was created in 1926 has evolved over the years into what is known today as the Twinlock winding crown, pressure-proof to 330 feet. The Triplock winding crown is pressure-proof to 1,000 feet on the Submariner and 4,000 feet on the Sea-Dweller.

1931: Rolex continued to improve its mechanical timepieces, perfecting and patenting the self-winding wristwatch. This was made possible by the invention of the first perpetual rotor automatic mechanism, the Rolex Oyster Perpetual.



1935: Sir Malcolm Campbell set land speed records of over 300 miles per hour in his specially designed race cars, accompanied by his Rolex timepiece.

1945: Rolex created the Datejust, the first pressure-proof, automatic wristwatch chronometer that showed the date in a small "window" on the face of the watch.

1947: World War II flying ace Chuck Yeager, wearing his Rolex Oyster Perpetual, breaks the sound barrier. Yeager was only 24 years old at the time.

1953: Edmund Hillary and Tenzing Norgay are the first to conquer Mt. Everest. The expedition's teamwork was synchronized on Rolex timepieces. Rolex created the first pressure-proof, automatic timepiece, the Oyster Perpetual Submariner, certified to 300 feet. Today's Submariner runs even deeper, and is certified to 1,000 feet.

1960: Dr. Jacques Piccard breaks the world record with a 35,000-foot deep-sea dive in the Pacific Ocean with a Rolex Oyster strapped to his bathyscaphe. This historic watch resisted over a ton of pressure per square inch.

1971: Rolex creates the Sea-Dweller, the first diving watch in the world with a helium escape valve that allows the expanding gases within the case to be released during the diver's ascent to prevent explosive decompression of the watch.

Performance.

The Wahiba Sands Expedition in the Sahara.

1986: The Royal Geographical Society scientists studying Wahiba Sands in the Sahara rely on Oyster timepieces to withstand desert sand and extremes of temperature.

1994: With his third win at Le Mans and his tenth endurance championship, Hurley Haywood breaks his own record set in 1991 as the race car driver with the most endurance wins.

Yesterday becomes today.

Steve Wand at the controls of the Concorde simulator.

Since its founding, Rolex has continued to set extraordinarily high standards for all of its timepieces. They have been improved internally hundreds of times. Yet the GMT-Master II, worn today by Concorde pilot Steve Wand, looks, to the untutored eye, remarkably like the Rolex Oyster worn for over 25 years by Brian Trubshaw, who wore his as a Concorde test pilot in 1969.

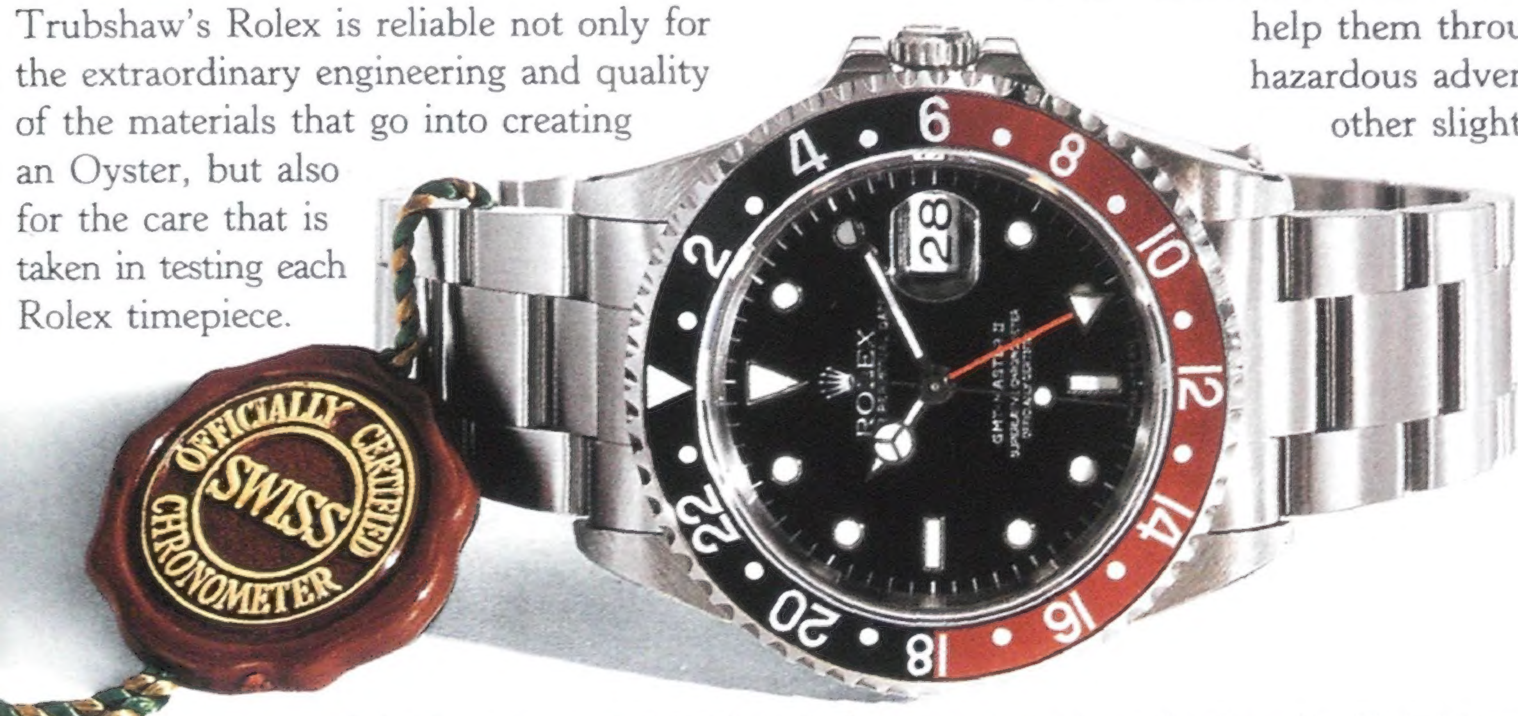
Trubshaw's Rolex is reliable not only for the extraordinary engineering and quality of the materials that go into creating an Oyster, but also for the care that is taken in testing each Rolex timepiece.

First, each Rolex Oyster is rigorously tested at Rolex, then sent to an independent Swiss Institute, the Contrôle Officiel Suisse des Chronomètres. There, each watch must successfully undergo fifteen days and nights of additional testing before it is awarded the prestigious red seal that signifies it is an Official Swiss Chronometer.

This painstaking process helps to explain why so many people today continue to count on the reliability and durability of Rolex. From conservationists like Dr. George Schaller working

Robert Anderson, making the first successful ascent of the west face, reaches the peak of Vinson Massif, Antarctica, via Rolex Ridge.

on the Chang Tang in Tibet to scientific teams crossing the Kimberley range in Australia. From divers like George Bass timing their ascents from the depths off Turkey to climbers like Robert Anderson challenging the heights of the world's tallest mountains. They rely on Rolex to help them through their often very hazardous adventures. As do many other slightly less-adventurous souls all over the world.



ROLEX

Rolex Oyster Perpetual GMT-Master II Chronometer in stainless steel with matching Fliplock bracelet.

Write for brochure. Rolex Watch U.S.A., Inc., Dept. 120, Rolex Building, 665 Fifth Avenue, New York, N.Y. 10022-5383.

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Back in 1949, computers took up the space of entire warehouses. So as unrealistic as this quote might sound now, it was actually pretty optimistic thinking at the time.
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April/May 1996
Volume 11, Number 1

AIR&SPACE
Smithsonian

SPECIAL 10TH ANNIVERSARY ISSUE!

+10

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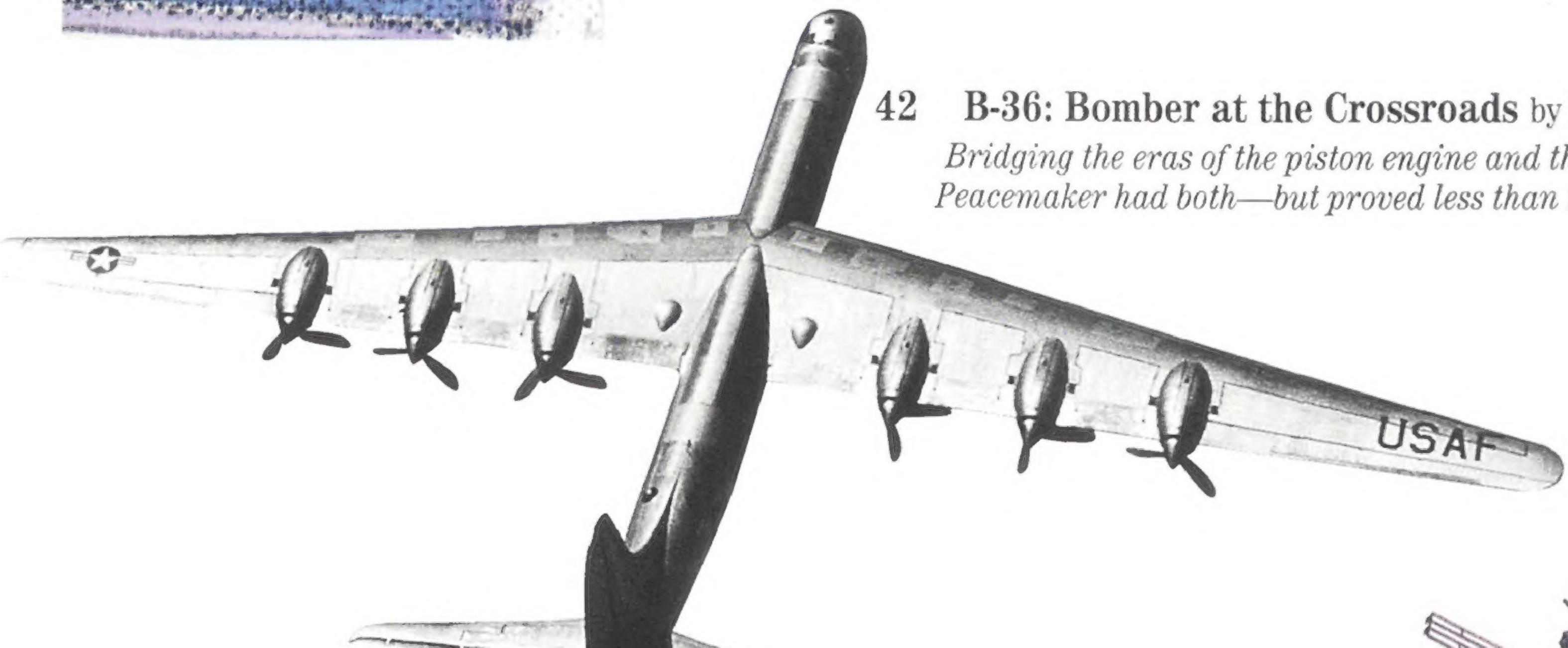

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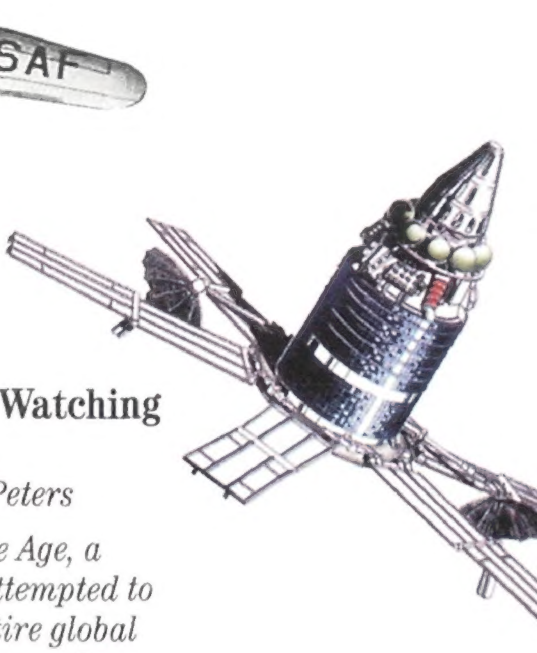

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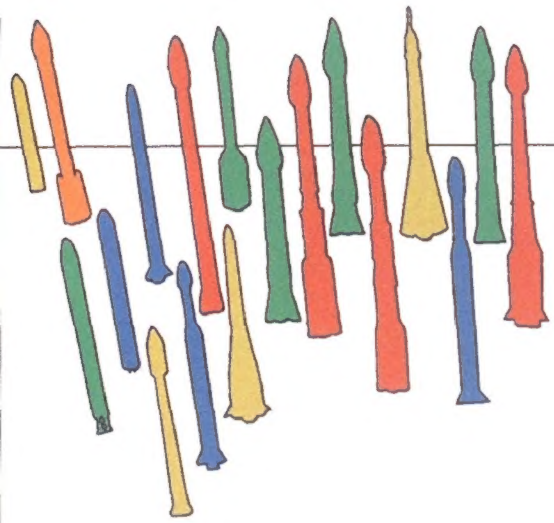

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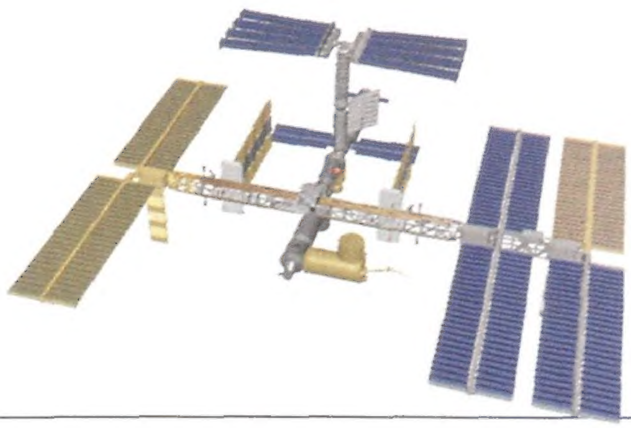

Cover: *Artist Ron Kaplan (left) painted our cover's nose art on a privately owned B-25; pilot and photographer Dan Patterson (right) arranged for the airplane's loan and shot the end result. The World War II-era bomber had a special significance to Kaplan, whose father was a B-25 pilot. Kaplan also appreciated the fact that the bomber was indoors: He painted the nose art while the outside temperature was below zero (for more information on the making of our 10th anniversary cover, visit the magazine's Website at www.airspacemag.com/10th/Cover.html).*

DAN PATTERSON

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Caravan Sport. For all th

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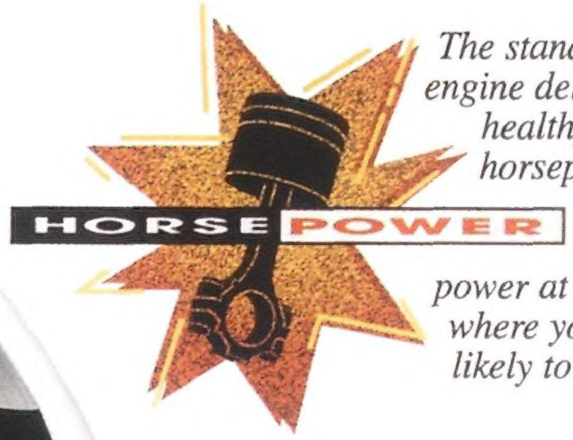

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The New Dodge Caravan

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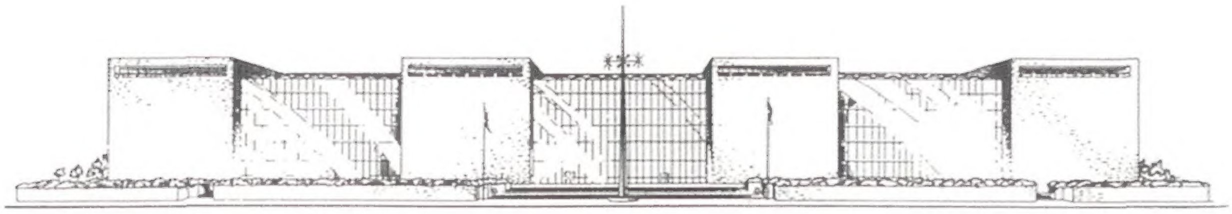
VIEWPORT



Ten, Going on 100

Ten years ago, the Smithsonian Institution launched this magazine to explore the ramifications of two fundamental ideas: that the invention of the airplane was a gift to humankind, and that this gift turned around and reinvented us, permanently altering our view of the world around us. As part of this mission, we have strived to illuminate some corners of history that had seen too little light.

Stand back and view the history of the airplane at arm's length and you'll see nearly 100 years (the century mark is only seven years away) divided roughly in half by a single development: the jet engine. Not long after the Wrights invented it, the airplane had settled into a standard shape: straight wing with stabilizing surfaces on the tail plus engines driving propellers mounted in the tractor configuration. But after the turbojet came along, a whole new realm of aerodynamics was opened up, and the airplane changed completely. It looked different, it flew differently, and its economics changed—the last factor having its greatest impact on the airline business.

Everyone seemed to sense that the turbojet engine defined the airplane's destiny. My father was not an aviator, but he'd worked at an aircraft plant as a draftsman, and he knew something big had happened. We spoke in awed tones about something new called "jet propulsion," and when we saw the first of these new craft, their speed was breathtaking. They had swept wings and they sounded like rockets, and you learned that when you heard a jet passing overhead, you had to look well ahead of the sound to find the airplane. Whereas the Connies and DC-7s departing New York's LaGuardia for the west used to wake the dead as they groaned upward at a few thousand feet during the long climb to altitude, the 707s that whispered past us a few years later were already tiny silhouettes by the time they reached our house.

The 10-year mark is always an appropriate time to pause and look back, but it also affords an opportunity to look forward, which is even more interesting.

When the turbojet arrived, it seemed unbelievable; it was certainly unanticipated by us, the unschooled, who couldn't have known it was inevitable. Now there is a feeling that we're overdue for the next great leap, something wonderful that is impossible to envision but just over the horizon. You can almost hear the silence as we all wait for the trumpets' call. It may have something to do with a breakthrough in our understanding of gravity. Or perhaps we'll develop some new principle of propulsion. Whatever it is, we know that human ingenuity delivers advances at a certain pace, and the time has come for another.

If that isn't enough stimulation, talk to some young astronomers or astrophysicists. You'll get a sense of acceleration, a growing feeling that we're nearing something momentous. With the new generation of space-based instruments and wondrous ground-based telescopes, the number of astonishing images that answer old questions are vastly outnumbered by those that only raise new ones. Wherever you go, it is as if a wind were rising.

Astronomers are peering so far back into time that they sense they are close to seeing its origin, and talk about the stars is merging with talk about the creation of the universe itself. Astronomers are talking these days about God, not so much in the context of religion as in the context of the unknown.

If you've been reading the papers over the last decade, you've learned that the aerospace business is shrinking and the entire landscape is changing. All that is true, and it can't be minimized. At the same time, we can't escape our own history: We've never stopped being curious, and we've never stopped inventing. It's part of our nature. That's what makes it fun to publish this magazine. So for us at *Air & Space/Smithsonian* at the 10-year mark, this is a pretty good time to be alive.

—*George C. Larson*

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Poor Visibility

Your editorial "Fly United" (Viewport, Feb./Mar. 1996) struck a chord deep within me. When I was a college junior in 1968, I purchased a cheap multi-band radio that included the VHF aviation band. I used to visit all of the airports in the San Francisco Bay Area, park at good vantage points, and watch the planes while I listened to the control tower. This hobby started my aviation education and cemented my relationship to aviation, which has lasted to this day.

Many flying hours and almost three decades later, I revisited all of my old haunts with a state-of-the-art VHF/UHF scanner. I was stunned to find that all of the airports had segregated or were in the process of segregating the public from all aviation activity. At most fields I could not get close enough to view the takeoffs and landings.

The siege mentality responsible for this kind of segregation tends to alienate non-aviators and potential flying students, as well as strengthen the position of those who would close our small airports. No doubt a lot of the problem stems from an overzealous Federal Aviation Administration, but I believe others are to blame as well—airport management, airlines, and private pilots among them.

—Manny Interiano
San Jose, California

A Proud Piper Papa

From the beginning, we were convinced that the Piper Cherokee PA-28 was going to be a good airplane and, with our sales organization behind it, a very good seller. But we had no idea that it would be in production for so long and that it would still be going strong as we approach a new century.

After reading "The Big Ten" (Feb./Mar. 1996), I went back to my files to check on a few dates. My first layout for the PA-28 was dated October 9, 1957, shortly after I left North American

CONSTANTIN PAVEL

Aviation to work for Piper. The complete layout and inboard profile, the definitive specifications, and the original loads analysis were dated March 15, 1958. By that time, we had hired a few detail designers and the project was on its way.

A few modest corrections to your article: The original PA-28s were not C models. They had no letter designation. About a year after first deliveries, we came out with B models of the PA-28-150 and -160. They had a number of improvements, including Dynafocal engine mounts. The original PA-28-180 was a B model. The C model incorporated the first of the all-composite two-piece cowls.

—Karl H. Bergey
Chairman, Bergey Windpower
Norman, Oklahoma

At Wicks' End: The Untold Story

Whoever told Arnold Benson about Gordon Wicks' demise gave him a bum steer ("At Wicks' End," Above & Beyond, Feb./Mar. 1996). I served as a pilot instructor with Gordon at Laughlin Field in Del Rio, Texas. Following is the actual story.

Before Gordon crashed, we used to enter the pattern on a 45, advance the prop pitch, check the mixture controls, and settle down to about 160 mph on the downwind leg. After turning on the base leg we'd drop the landing gear and turn on the approach. Then we would drop the flaps, usually using full flaps for landing.

On his last flight, Gordon went through all of these procedures properly, but only the flap on one side came down. The plane did a snap roll on the approach, and Gordon had absolutely no time to recover at the low speed and altitude at which he was flying. His plane augered in at the end of the runway, killing all on board.

After that, we started a new procedure: checking our flaps on the base leg by dropping them about a quarter. Because of Gordon's sacrifice, other lives were likely saved.

—Lt. Col. William R. Maxson
U.S. Air Force (ret.)
Hartsville, Pennsylvania

Kind of a Drag?

Why were the F-100s described in "Runways of Fire" (Oct./Nov. 1995) launched with the landing gear extended? Wouldn't withdrawing the wheels have reduced the drag of the jet and the energy required by the rocket during launch?

—Nico Georgeoglou
Athens, Greece

Al Blackburn replies: The F-84G was launched with the landing gear retracted. Since a mat landing was envisioned, there was indeed no need for the gear, so it was withdrawn.

When the mat landing concept was abandoned, however, it was decided that for the F-100, using the landing gear would be the best way to put the aircraft on the launcher and raise it to the 30-degree launch angle. The drag created by the fully extended gear was quite small; in fact, more would have been created by opening the gear doors during the retraction cycle. (This was not true for the F-104; on that aircraft, the gear was extended for launch but retracted during the boost period.)

There was another reason for leaving the gear down: If the aircraft made an unprogrammed contact with the ground at a high sink rate, the gear would absorb a lot of the shock. Bob Hoover made such a landing in an F-100 on the Edwards lake bed, and I made one in an F-86 in the desert near China Lake. We are convinced that having the landing gear down saved our lives (though not the airplanes).

"Not only is this asteroid hurtling toward Earth, computer-enhanced photos indicate there's a note tied to it."

Imagine How the Birds Will Feel

The thought of commercially viable roadable aircraft ("Auto Pilots," Dec. 1995/Jan. 1996) conjures up the picture of hundreds of small aircraft being flown by pilots with a wide range of training and experience, all converging on airports around the country. The prospect can be described in just one word: terrifying.

—I.J. Moore
El Cajon, California

More Thoughts of a Religious Nature

As one who holds members of the clergy in high esteem, I was unsettled to read Edwards Park's account of the seemingly cavalier attitude he and his fellow soldiers had toward the war, their situation, and the chaplains ("Landing Rites," Flights & Fancy, Dec. 1995/Jan. 1996). Upon further reflection, though, I was reminded of a letter my brother sent my family while he was based in Thailand during the Vietnam war. He was flying F-4s and was 50 missions toward his 100th. His letter began simply: "Still alive and kicking!" That short phrase brought home to me the uncertainty those living the war faced and could conquer only one day at a time. This was no cavalier attitude. Nor was it the attitude of the warrior we liked to believe was fighting for us and our country. It was a simple expression of the deep feelings of one man dealing with a deadly situation.

Never having been in war, I am not in a position to judge these men's attitudes. Edwards Park, through his intimate contact with war, has opened a door ever so slightly and given those of us not familiar with war a glimpse into a world in which we hope never to find ourselves.

—Patrick G. Mawhinney
Duluth, Georgia

Corrections

Feb./Mar. 1996 "The Big 10": The first production C-130 was retired last September. Prior to that, it served with the 711th Special Operations Squadron at Eglin Air Force Base's Duke Field in Florida.

Dec. 1995/Jan. 1996 "The Road Show": Gordon Cooper was the fourth American to orbit Earth, not the fourth in space.

Oct./Nov. 1995 "Runways of Fire": Though a version of the Harrier was eventually adopted by the U.S. Marines, the original design was developed by the British.

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Gentlemen, Start Your Scramjets

Before the era of big government projects like Apollo and the shuttle, private funds were offered to reward private initiative. For his nonstop New York-to-Paris flight, Charles Lindbergh won the $25,000 Orteig prize. Other prizes that spurred aviation development were known by donor names like Guggenheim, Bennett, Kremer, and *Daily Mail*.

Now a committee of aerospace supporters is proposing a competition for the "X" prize, a $10 million purse to be awarded to the first team of entrepreneurs that builds a space vehicle and launches a series of suborbital flights.

For now, the "X" prize is named to evoke images of such pioneering experimental vehicles as the X-1 and X-15. When a major donor steps forward, the prize will bear the name of that group or individual. Fundraising is set to begin in May with a series of kick-off events in St. Louis.

At that time, the qualifications for winning the prize will be announced, such as number of flights, time constraints, altitude, and payload. One of the prize supporters, Apollo 11 astronaut Buzz Aldrin, has urged that the goals be clearly attainable. "I want to see progressive movement toward tourism in space," he says. Other committee members include experimental aircraft builder Burt Rutan, space entrepreneur Peter Diamandis, Charles Lindbergh's grandson Erik, and undersea explorer Sylvia Earl. The effort is endorsed by the National Space Society and the Association of Space Explorers.

So far, promoters point out, we have succeeded in putting humans in orbit and on the moon, but only a small corps of highly trained astronauts and cosmonauts. To build a "space-faring civilization," they argue, transport costs must be reduced, particularly in a time of government retrenchment.

Just as the Orteig and other prizes stimulated continuing commercial development of aviation, the "X" prize is intended to do the same for space tourism. This won't be a one-time "Evel Knievel-like stunt," stresses Lori Garver, executive director of the National Space Society. Peter Diamandis, chairman of the "X" Prize Foundation, predicts, "While there will only be one winner of the 'X' Prize, there may be as many as a dozen or more alternate efforts trailing close behind, all of which will strive to commercialize their vehicles and recover their investment."

After the suborbital flights, space advocates like Garver and Diamandis envision more prizes to reach more distant goals: commercial vehicles able to carry tourists into orbit, to the moon, and on to Mars. The incentives needed to entice entrepreneurs to the Red Planet, by one estimate: $41.5 billion for 12 prizes.

—Lester A. Reingold

UPDATE

Collectible B-52s

The Beverly Hills Air Force, a group of California investors, has purchased innards from decommissioned B-52 bombers and is selling such items as flight instruments and ejection seats ("Death of the Beast," June/July 1995). Prices range from $150 for a fuel gauge to $5,000 for an eight-engine throttle quadrant. Call (800) 355-2423 for a catalog.

RICHARD SASSAMAN

Picture Your Name Here

Black marker in hand, I walk over to the North American Harvard Mk.IV. An export version of the AT-6 Texan, the bright yellow 1951 trainer has been meticulously restored for the Canadian Warplane Heritage Museum in Ontario. I stand with the pen and wonder where to deface the airplane.

I won't be the first to write on it—or the second, the third, the 100th, or even the 500th. (Number 500 was a pilot from Nigeria who signed it at the Hamilton Airshow.) The Harvard is covered with a rambling welter of a thousand signatures, drawings, ads, and pleas for attention. "Sonia: Can I Even Have Your Phone Number?—Bill" is written on the left side of the tail. "Apr. 30/95 Arvid Monen! (Rankin Inlet, NT) Marry me now or else. Love, Kim Southcott (Gimli, MB)" appears under the right side of the cockpit. It's a proposal from a Manitoba woman, written at the Toronto Aviation Show to a man in Canada's Northwest Territories. Museum officials photographed the proposer with the airplane and mailed the picture off, but no one's heard anything back yet.

"Dakotas Eat Harvards. DAKs forever."

"The Hang Gliding Shop, Toronto."

"In memory of Captain T.G. Gordon, Trained R.C.A.F. Harvard Centralia Ont. No. 1 FTS" says a dedication signed by the captain's son and daughter.

For a contribution of $20 to the museum, you can write or draw whatever you wish on this classic aircraft as long as it fits in a rectangle four by 14 inches. The autographing idea came from museum mechanic Steve Martin, who saw a photo of the last B-25H built. North American had everyone involved in its design and production sign the airplane, providing a way for workers on the home front to feel like a part of the war effort. The museum adopted the tradition to help raise money for a new $12 million building following a 1993 fire that destroyed one of its two hangars.

The project is sponsored by Ontario's Falcon Aviation, explains the museum's Richard Moos. "They're a firm that paints airplanes commercially and they want to move into doing warbirds," he says. "Our goal is to gather 2,000 signatures by the middle of 1997, at which point the plane will be photographed, stripped, and repainted."

Several people at the museum, referring to this plan, wistfully note that they are growing quite fond of their graffiti-covered airplane. "So many people at airshows are like 'Get away, don't touch my plane,' " says Bert Brown. "And here we are, with our Harvard, saying, 'Go ahead, write all over it.' "

—*Richard Sassaman*

UPDATE

Cuba Downs Civilian Craft

Last February two Cuban MiG-29s without warning shot down two Cessna 337 Skymasters belonging to the Florida-based Cuban exile group Hermanos Al Rescate, or Brothers to the Rescue (Soundings, Dec. 1994/Jan. 1995). All four crewmen aboard the Cessnas, including pilot Carlos Costa, are missing and presumed dead. Cuba claimed the aircraft and "pirates" had violated the 12-mile Cuban airspace limit; the U.S. government denied it. Hermanos president Jose Basulto, the pilot of a third aircraft that was not shot down, said the Cessnas were searching the area for Cuban refugees in makeshift rafts and admitted that his aircraft had flown three miles into Cuban airspace. The Federal Aviation Administration had issued warnings to Basulto about the perils of flying over Cuba.

SETI on a Shoestring

What if ET does phone home—but no one is listening? Though four SETI (search for extraterrestrial intelligence) radio telescope projects are currently listening for alien signals, they can monitor but a fraction of the sky. Paul Shuch, an electronics professor at the Pennsylvania College of Technology in Williamsport, has a plan: He has organized the 300-member SETI League, which on April 21 will begin constructing a global all-sky survey using common backyard dish antennas.

The concept's not as farfetched as it may sound, according to Shuch. Your average parabolic antenna needs only a few thousand dollars' worth of modifications to be converted into a radio telescope, including a special feed horn (the device in the dish's center), a microwave amplifier and receiver, and a personal computer, which will analyze any anomalous signals it receives, then alert the operator and his fellow Leaguers on the Internet.

Seth Shostak, an astronomer at the unrelated SETI Institute, says this is a viable effort. "There are analogs in conventional astronomy research where amateurs dominate, like searching for comets," he says. But the big problem with small dishes, he adds, is a lack of sensitivity. "An antenna is essentially a bucket collecting signals," Shostak says. "A bigger bucket can collect more signals." The largest antenna the institute uses, in Arecibo, Puerto Rico, is 50,000 times more sensitive than the average backyard dish.

"It's a valid criticism," says Shuch, "but who knows how often a strong signal has been missed because a SETI project was not funded or was turned off or wasn't pointed in the right place? Let's start with the technology we have, and the worst thing that can happen is we'll develop technology with other applications."

Using those ubiquitous backyard antennas to search for extraterrestrial intelligence has been a dream of Shuch's since he designed a commercial home satellite dish in 1978. Eventually, Shuch hopes to enlist a total of 5,000 dish owners.

—*Phil Scott*

Satellite for the Common Man

Need a last-minute gift for a friend who has everything? For a cool $100,000 you can get a tiny satellite with solar panel, three-axis attitude control, lithium-ion battery, eight-volt power bus, 32-bit microprocessor, and eight-megabyte data storage. It's called a Bitsy, and not only is it the cheapest satellite on the market today, but at a mere two pounds, it's also

the lightest. And it's compact enough to stuff in a camera bag. Try that with your typical two-ton satellite.

Tomas Svitek, the Czech-born Bitsy program manager at AeroAstro in Herndon, Virginia, predicts that the multi-purpose Telstars and Solar Maxes of yore will yield to networked constellations of single-purpose itsy Bitsys. But aren't satellite orbital belts already too crowded? "Space is huge," Svitek maintains, "and it will not get filled up that easily." Anyway, he adds, after a couple of years each microsat's orbit will decay and Bitsys will burn up as they reenter the atmosphere, creating a market for replacements.

The U.S. Air Force has signed up for three Bitsys and plans to start launching them for test applications next year. But AeroAstro wants to sell to commercial organizations for whom satellite technology has been out of financial reach. (The typical satellite runs $200 million.) And, Svitek says, Bitsy buyers will concoct an array of applications: keeping track of livestock or small truck fleets, perhaps, or reading specially equipped utility meters. Buyers could keep tabs on their kids, pets, neighbors, or even Iraq: Svitek says AeroAstro will customize each satellite to fit customer needs.

Still, the price tag doesn't include extras like those custom mods, a ground station, launch insurance, or even the launch. For all that, plan on spending around a million dollars.

—Phil Scott

More Than Just Another Pretty Face

Used to be that well-worn Air Corps leather was the ultimate in aviation chic. No more. Enter Emergency, the gizmo-golliest aviation watch ever.

Made by Breitling, the Swiss watchmaker whose very logo has wings, Emergency is the most extraordinary of the company's multi-dialed timepieces. Both a chronograph and a watch, the $4,500 device monitors two time zones and presents the day in English, Spanish, or French along with the date. It features a timer, alarm, sapphire crystal, and titanium case, and it's water-resistant down to 100 feet. But what sets Emergency apart from other chronographs is the slightly oversize thumbscrew near its four o'clock position. Give the screw a couple of counterclockwise turns and pull, and out comes a thin 17-inch wire. Remain calm, stay warm, and don something orange. You've just summoned the Civil Air Patrol and who knows what else.

The wire is an antenna for a transmitter housed in the watch and set to 121.5, the international emergency frequency. Extracting the antenna triggers the transmitter, and there is no OFF switch.

Despite the transmitter's diminutive size and two puny three-volt lithium batteries, Breitling says that under optimal conditions the signal will broadcast up to 250 miles for 48 hours. It's designed to complement the signal from a crashed aircraft's emergency locator transmitter, which is triggered when the device senses two to seven Gs of force for several milliseconds.

"Oh, no, that's all we need: another radiating device on 121.5," says one Civil Air Patrol official. Since virtually every airplane and yacht is equipped with an automatic (and often malfunctioning) emergency transmitter, and since everything from microwave ovens to fax machines are leaking signals in the 121.5 MHz range, the channel is getting noisy. Nearly all the messages—around 97 percent, says the CAP—are bogus. No more false alarms, thank you, says the search-and-rescue group, least of all from Top Gun wannabes who can't resist trying out their latest toy.

Breitling says it will restrict Emergency sales to pilots, but the CAP is skeptical about the company's ability to maintain such control. If the device is abused and a full-scale air, land, and sea search results, the Emergency wearer will be charged every penny of its cost.

—William Garvey

BREITLING

UPDATE

Astronomical Findings

A team of U.S. astronomers announced last January the discovery of two planets outside the solar system, one in the constellation Virgo and one in the Big Dipper ("The Planet Hunters," Oct./Nov. 1992). The star 70 Virginis is orbited once every 116 days by a planet eight times the size of Jupiter, with a surface temperature of about 185 degrees Fahrenheit. In the Big Dipper, the star 47 Ursae Majoris is orbited every 1,100 days by a planet three times the size of Jupiter and with a temperature of −112 degrees. Both planets are thought to be capable of sustaining water and organic molecules.

An international team of astronomers has determined that at least 50 percent of the universe's "dark matter" consists of burned-out white dwarf stars called Massive Compact Halo Objects, or MACHOs ("The Case of the Missing Matter," Feb./Mar. 1993). Researchers monitored 10 million stars in the Large Magellanic Cloud nightly and over two years observed seven "micro-lensing" events, in which a background star "brightens" due to the gravitional field of a MACHO passing in front of it, bending its light rays. An earlier search employed restrictive object-size parameters and revealed only three micro-lensing events.

Return of the Yak

A partnership between a Southern California entrepreneur and one of the former Soviet Union's most prestigious aircraft design bureaus has resurrected the Yakovlev Yak-3, a sturdy little fighter that wreaked havoc on the Luftwaffe in the closing years of World War II.

The project got its start in 1991, as the Soviet Union teetered on the brink of collapse. After meetings between Santa Monica businessman Alan Preston and officials of the Yakovlev Design Bureau in Moscow, Yakovlev and Preston's Flight Magic Inc. teamed up to restart a production line that shut down more than

MICHAEL O'LEARY

50 years ago. The venture produced 10 new Yaks, most of which have been sold to collectors. One was shipped to the Alpine Fighter Collection in New Zealand. Priced around $450,000, a factory-new Yak-3 sells on the collector's market for a little less than a vintage P-51 Mustang.

"My personal interest has always been the warbirds that are virtually nonexistent," says Preston, a director of the Santa Monica Museum of Flying. "I've been fascinated by planes that were great contributors in the second world war but that were little known in the West. The incentive for us was not economic so much as to see them up and flying. The design bureau was [just] trying to make some aircraft to sell."

Jane's All the World's Aircraft calls the Yak-3 "the lightest and most agile monoplane of World War II." Today, only two original Yak-3s are known to exist. One, owned by the Yakovlev Design Bureau, was loaned to the Santa Monica museum. The other is in the Musée de l'Air at Le Bourget, France. The newly minted Yaks rolled off the factory line with serial numbers sequential to the last one produced at the end of World War II.

Drawings and jigs for the fighter were stored at Yakovlev, but the V-12 Klimov engine that powered it no longer existed. An Allison V-12, which also powered P-39s and P-40s, was substituted. Painted slate gray, the fighters sport a bold red star and nose art of a knight armed with a lance. "It's from the Middle Ages: one of the main symbols of all Russian warriors, the knight George, with a dart to strike a snake," says Sergey Konyavko, a Russian émigré who works with the Museum of Flying's hangar crew. "Stalin decided to pick up this symbol for patriotic purposes."

"It's a great little dogfighter," says Bruce Lockwood, who supervises assembly and flight testing at the museum's Mojave facility. "It was the most underrated fighter of the war because so few people outside Russia knew about it." Last September, Lockwood, flying a new Yak-3, won a bronze medal at the Reno air races.

"A guy who wants one airplane is usually thinking about a Mustang," Preston says. "A collector with multiple airplanes thinks about historical significance and the impact on his collection. I really wanted one. It handles like a sports car."

—*Dennis Anderson*

UPDATE

East Meets West

In a deal arranged last January, the U.S. government agreed to loan the Russian airline Aeroflot $1 billion to finance the construction of 20 wide-body Ilyushin Il-96M airliners ("Unfriendly Skies," Aug./Sept. 1994). In return, Russia agreed to suspend a 30 percent tariff on imported Western airliners. Boeing had stridently opposed the loan, viewing Russia as a potentially strong competitor, but was mollified by the removal of the tariff. It is estimated that Russia will buy or lease $75 billion worth of Western aircraft in the next two decades.

Vietnam Airlines ("Passage to Vietnam," Oct./Nov. 1995) has leased 10 Airbus and three Boeing airliners through Regionair and GE Capital Aviation Services. The airline plans to double its fleet in the next four years by exchanging its older Tupolev 134s and Yak 40s for state-of-the-art aircraft like the Airbus A320 and Boeing 767-300.

Stephanie Maze used a remote camera to take the photograph of the biplane that appeared on the first issue of Air & Space/Smithsonian, dated April/May 1986. In the 10 years since, the magazine has looked at all forms of flying things, from angels to zeppelins.*

To celebrate the 10th anniversary of *Air & Space/ Smithsonian*, we reflect on how time flies.

Ten years ago, the Smithsonian Institution launched this magazine as the official publication of the world's most visited museum—the National Air and Space Museum. As it happens, the 10th birthday of *Air & Space/Smithsonian* magazine coincides with the Museum's 20th anniversary and the Institution's 150th, so 1996 is nicely packed with cause for celebration around here.

In this special anniversary issue, we decided to explore the significance of a 10-year span by looking at a number of aviation milestones from the perspective of a decade hence. In most cases, the view is surprising. It turns out that a decade is about the amount of time it takes for us humans to absorb the full import of a major development and begin to make some sense of it. And that may help to explain why the stories in this issue all have a consistency of irony.

In the 10 years since this magazine's premiere issue, we've learned that flight remains one of the most dramatic, exuberant, and imaginative enterprises the human species has ever undertaken. While its seeming defiance of nature may have once frightened some, the art and science of flying have evolved into something loosely described as "aerospace," a term that embraces a continuum, a historic arc that started with the airplane and currently reaches to the Voyager spacecraft, which should leave the solar system very soon for interstellar space.

Throughout its short history, flying has drawn a community that faces forward, looking toward the next machine, the next technique, and the next destination. Remarkably, when that community moves forward, even in wartime, it moves in approximate unison. The lead may change from time to time, but the whole gaggle competes with a tacit consensus. And there's a reason for that.

Although we've moved from building airplanes in the *ateliers* of France to stacking spacecraft in buildings big enough to have their own weather systems, we still take each step with one foot firmly planted on the step we'd taken just before it. Even something as seemingly revolutionary as the turbojet is really derivative. Now the organizations are bigger, and while that makes it more difficult for us to identify individual heroes and propel them into the public spotlight the way we used to, it hasn't reduced the overwhelming urge to glance backward to the past just before we take each step into the future.

Flight, whether in airplanes or spacecraft, has always seemed an activity that is inherently futuristic. Flying feeds on tomorrows and peeks fearlessly around corners. There is a certain restlessness that has always characterized the industry that builds flying machines and the people who fill its ranks. For all the sureness of our footing, though, we're never really quite sure what's going to happen next. So as you read these tales of what transpired in the "Ten Years After" aviation's milestones, don't judge the decisions of the past too harshly. Everything seems so clear when we glance back, but looking ahead—or even grappling with the present—is the hard part.

—The Editors

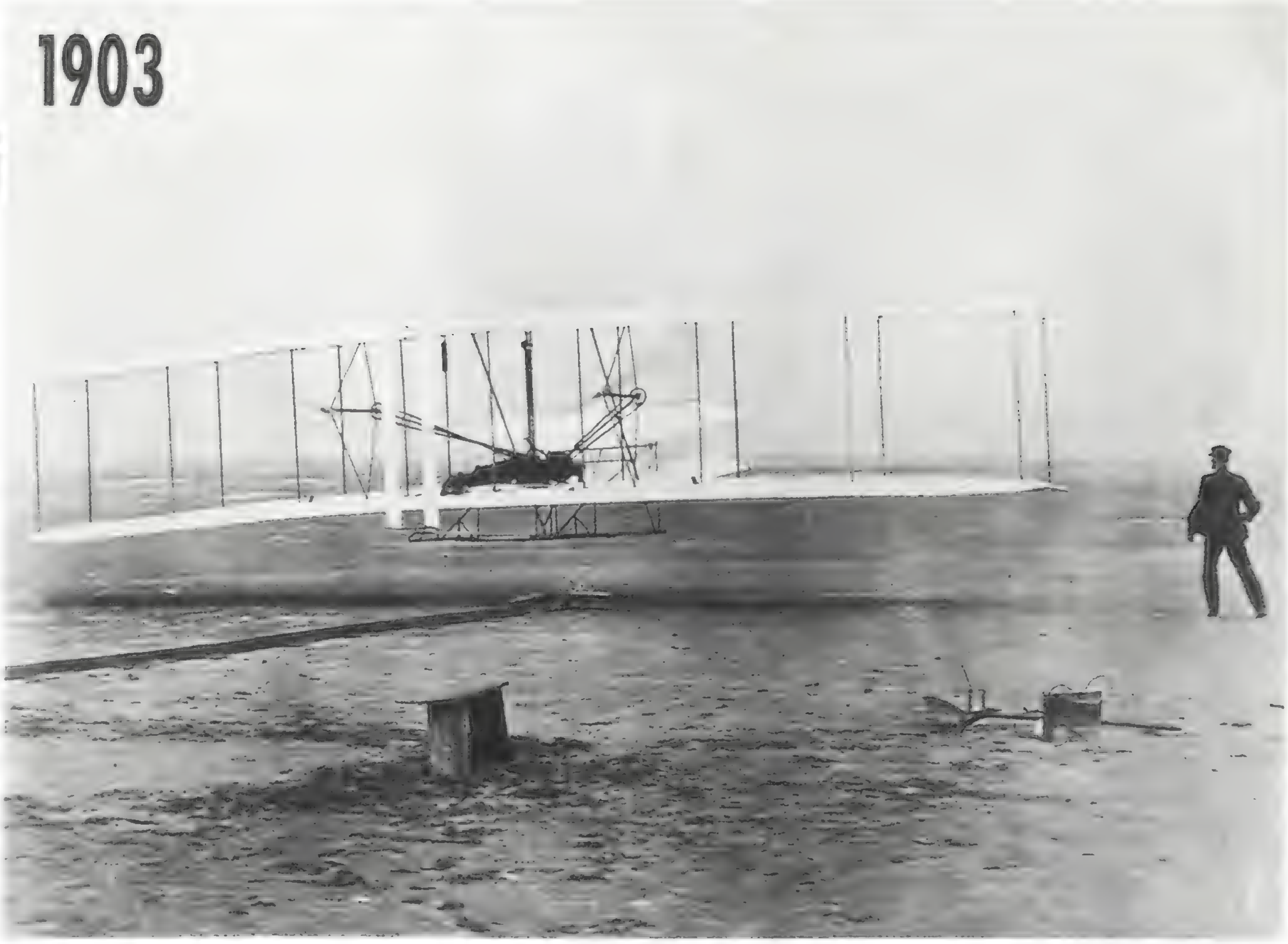
The Milestones

December 17, 1903
The Wright brothers make the first fully controlled flight in a powered aircraft. Interestingly, the brothers soon lose their initiative, and within just 10 years the world's aeronautical center of gravity has migrated to France.

May 21, 1927
Charles Lindbergh accomplishes his great leap across the Atlantic to Paris in order to win a big check from a French-born businessman, although we now look up at the *Spirit of St. Louis* in the National Air and Space Museum and see the symbolic beginning of routine transoceanic travel. Ten years after Lindbergh's flight, though, leaders on both sides of the Atlantic have yet to construct something as seemingly obvious as paved runways to handle the coming stream of airliners.

August 27, 1939
The first jet engine makes a successful flight aboard the experimental Heinkel He 178 airplane. Yet even with the pressure of a world war, this breakthrough in propulsion is only barely noticeable toward the end of World War II. A decade after that first flight, the turbojet will be powering U.S. fighters but only hesitatingly applied to bombers, a fact that will haunt the Air Force's giant Convair B-36—the last pro-

NASM



MIR AGENCY

NASA (3)

peller-driven bomber in service—from the day it is rolled out. Caught in the transition between reciprocating engines and jets, the big bomber becomes a symbol of obsolescence.

October 4, 1957
The launch of Sputnik 1 opens the Space Age and makes the space race one of the centerpiece battles of the cold war. Ten years after that big surprise from behind the Iron Curtain, both East and West are using satellites to spy on one another—but they are also moving toward uniting the globe with satellite-based telecommunications.

July 20, 1969
The Apollo 11 moon mission creates a feel-good mood among Americans, but 10 years later a European rocket, in a come-from-behind stretch run, is moving toward the dominant position in the launch business, mostly because it began treating satellite launches as exactly that—a business.

January 28, 1986
The shuttle *Challenger* is destroyed, derailing the U.S. space effort for more than two years. In the weeks that follow, the cause of the tragedy is identified as a faulty solid rocket booster. Ten years later the shuttles are flying with a redesigned booster, but the shock of the *Challenger* disaster continues to reverberate.

The Future—2006
What will aerospace look like a decade from now? We asked some would-be visionaries to predict advances that will make the most difference. In *Air & Space/Smithsonian*'s 20th anniversary issue, we'll tell you how they did. Watch for it on a holographic newsstand near you!

ALL PHOTOGRAPHS COURTESY NASM

AVIATION'S BELLE EPOQUE

THE AIRPLANE MAY HAVE BEEN BORN IN THE UNITED STATES, BUT IT UNDERWENT ITS ADOLESCENCE IN FRANCE.

By Robert Wohl

Late in the summer of 1908, on a racetrack near the French city of Le Mans, Wilbur Wright climbed into his Flyer to show a disbelieving nation that his machine did indeed fly. Wright's long-term goal was the establishment of Wright-licensed factories in France, but his demonstration flights had another effect altogether: They set the French to creating their

own aircraft industry at a giddy pace.

During the four years that followed Wright's return to the United States in 1909, the French dominated almost every aspect of flying. In 1913 Maurice Prévost, flying a sleek Deperdussin monoplane, won the Gordon Bennett race at Rheims with a speed of almost 127 mph, beating by about 27 mph a record set the previous year by another Deperdussin. The same year, Roland Garros crossed the Mediterranean in a Morane-Saulnier monoplane, while Marcel Brindejonc de Moulinais flew a Morane-Saulnier 870 miles from Paris to Warsaw in a single day, more than 11 times the distance Wright had covered in a two-hour Michelin trophy flight in December 1908. The French had taken Wilbur Wright's lessons to heart,

Wilbur Wright's demo flights in France in 1908 and 1909 brought traffic—and disbelief—to a screeching halt.

and their legacy has sprinkled aviation jargon with *aileron, longeron, fuselage, empennage,* and other Gallic terms.

Ten years earlier, however, when the Wrights made the first powered, con-

trolled, heavier-than-air flight, the world took perfunctory note of the achievement—then promptly forgot about it. Few suspected that the age of aviation had begun, and for good reason.

Previous claims of flight had proved unfounded, leaving skepticism in their wake. Just a week before the Wrights' December 17, 1903 success, Samuel Langley's expensive flying machine had plunged ignominiously into the Potomac River, earning it the derision of the *New York Times*. Then there was the fact that the Wrights' experiments had taken place on an isolated stretch of beach along North Carolina's desolate Outer Banks, far from the inquiring view of reporters. Transporting oneself to Kitty Hawk at the beginning of the 20th century, as the brothers discovered, was no easy matter.

Most important, however, was the Wrights' determination to keep their invention to themselves until they had developed it to the point where they could sell it at a handsome profit. Why give away secrets that others had struggled vainly to discover, secrets that governments had every reason to buy? Wilbur and Orville were convinced that they had time to spare because their American and European rivals were so far behind. Indeed, when the diminutive Brazilian dandy Alberto Santos-Dumont succeeded in raising his *14-bis* a full 10 feet above the ground over a distance of nearly 200 feet in Paris on October 23, 1906, most of those present went away convinced that they had witnessed the first true heavier-than-air flight. "The stupefied crowd had the

At the 1909 airshow in Rheims, France, lone American entry Glenn Curtiss (left) edged out Louis Blériot in the speed run. A popular model at the show was the Antoinette (below), as much a sculpture as an aircraft.

Gabriel Voisin's aircraft resembled box kites. They were well received: nine showed up for the Rheims meet.

impression of a miracle," flier Ferdinand Ferber wrote in his 1909 book *L'Aviation*; "struck dumb with admiration at first, they shouted with enthusiasm at the moment of the landing, and carried the aviator away in triumph."

But for all the excitement they generated, Santos-Dumont's 1906 hops had few immediate aeronautical results. The Wrights were correct in thinking that they were far ahead of their rivals in their ability to control a flying machine in the air. But they had overestimated the time their competitors needed to narrow the gap. With every month, the Wrights' lead dwindled. 1908 was the year of reckoning. It was then that flight was transformed from a curiosity without any evident future to a process with momentous, if for the moment unpredictable, consequences. And the stage of aeronautical activity moved definitively to France.

The year got off to a fast start on January 13, when Henri Farman, a former bicycle and automobile champion, completed the first publicly monitored circular flight of a kilometer on an airfield outside Paris. A few months later the American Glenn Curtiss celebrated Independence Day at Hammondsport, New York, with a flight of one mile in his *June Bug*. Feeling the pressure of the competition and convinced that the moment was ripe to cut a deal, Wilbur Wright sailed for France and inaugurated his season of spectacular flights in Le Mans, while Orville set out for Fort Myer, Virginia, to satisfy the conditions the U.S. Signal Corps had imposed for the Army's purchase of the Wright Flyer. On the last day of 1908, Wilbur Wright won the Michelin Cup by flying 77 miles in freezing temperatures. The next day, Georges Prade, one of Wright's most skeptical critics, conceded that, by his long-distance flights, his sudden climbs to 300 feet, and "his eternal and disconcerting circling above the heather of Auvours," the American had earned the title of "man of the year." Prade went on to apologize to his readers for having found "such a miserable epithet to characterize the man who will very likely be the man of the century."

Wright's fame in France, however, was destined to be more fleeting than Prade or Wright himself could have imagined, in large part because of critical decisions he made in the aftermath of his triumphant flights in 1908 and 1909. An aviation enthusiast who had traveled to France to see Wright fly, Lord Northcliffe, proprietor of the widely read newspaper the *Daily Mail* and one of the most powerful men in England, offered a prize of £1,000 ($5,000) for the first flight across the English Channel. Northcliffe tried to interest Wright in the exploit, privately guaranteeing him a $7,500 bonus on top of the public prize and half the net receipts from the exhibition of the Flyer in London. Wright was briefly tempted, but he demurred because of Orville's fear that the Flyer's engine was not reliable enough to make the Channel crossing and his own belief that "exceptional feats" were ill suited to the image of inventor that he was determined to cultivate for himself and his brother.

In the spring of 1909, after satisfying his contractual obligations to train selected Frenchmen and Italians to fly the Wright machine, Wilbur returned to the United States and devoted himself primarily to his business affairs. The aviator would increasingly give way to the capitalist, a change that did not sit well with Wright's admirers, not to mention his critics. It also opened a window of opportunity for the French.

With Wright out of the running for the *Daily Mail* prize, the favorite was Hubert Latham, a wealthy sportsman and man-about-town who had only recently learned to fly. Piloting a graceful Antoinette IV monoplane designed by the rotund engineer Léon Levavasseur, Latham took off on July 19 and was seven miles out to sea when his 50-horsepower water-cooled V-8 engine died. Unable to restart it, Latham glided down and alighted on the water, where a French destroyer escort found him a few minutes later, nonchalantly smok-

When Blériot staggered across the English Channel in July 1909 (left and above), France took the lead in aviation. For the next four years, French pilots claimed the records. In 1913 Roland Garros (right) became the first to fly across the Mediterranean.

ing a cigarette. When he arrived in Calais to a hero's welcome, Latham announced his determination to try again: "The Channel will be conquered. I'm starting over and I will succeed."

The Channel would indeed be conquered, but not by the debonair Latham. His place in history would be usurped by a dour French aviator and aircraft designer in blue coveralls. At daybreak on July 25, 1909, Louis Blériot succeeded in making the 23-mile crossing to Dover in 37 minutes despite his overheating 25-horsepower Anzani engine. The sight of ships steaming toward port had alerted him to change his heading, which was taking him toward the North Sea.

The French press immediately interpreted Blériot's exploit as a triumph of the monoplane—a French solution to flight—over Wright's American biplane, which, it was now remembered, had the additional defect of having to be catapulted into the air by means of a cumbersome derrick and rail. In the aftermath of the flight, while Blériot was being celebrated in London and Paris by huge crowds, orders for his flying machine, the Blériot XI, which was in large part designed by engineer Raymond Saulnier, began to arrive in droves. (Selling price in the United States was $850 assembled, plus $1,000 for an engine.) It would become one of the most popular aircraft of the pre-war period and would consecrate the reign of the monoplane. Favored by air racers, monoplanes proved speedier than biplanes, provided greater visibility, and were cheaper to maintain. But the monoplane's notorious instability and higher landing speeds produced a lengthy list of aviators who died at its controls. (In 1912, the French army grounded all Blériots after numerous fatalities caused by inflight wing failure, and England's Royal Flying Corps went so far as to ground all monoplanes.)

The French had further reason to celebrate their aeronautical achievements the following September at the conclusion of the great airshow at Rheims, which attracted 500,000 spectators, many of them dignitaries from France and abroad. Though Glenn Curtiss edged out Blériot in the 12-mile Gordon Bennett race, Blériot set a world speed record for a single lap—47.84 mph—and French aviators dominated all other events. Latham in particular dazzled the audience by ascending to an extraordinary 508 feet in his delicate dragonfly-like Antoinette monoplane, winning the altitude prize and leaving spectators with the impression that he was about to disappear in the sky. One awestruck German journalist wrote that it was a "picture more beautiful in its harmonic forms than one can imagine."

The next four years would see an extraordinary series of aeronautical breakthroughs. Speeds would be pushed to

Preceded by the Deperdussin monoplane, with its plywood shell (below and bottom), the Deperdussin monocoque of 1913 was one of the most advanced racers of the pre-war years (right). Its construction delivered structural strength in its skin, like an eggshell, and dispensed with birdcages of bracing.

more than 100 mph, distances would exceed 600 miles, and the altitude record would climb to above 20,000 feet. Airplanes would be spun, inverted, looped, and loaded with passengers, all at considerable cost in human life. In almost all of these areas of aeronautics, the French led the way.

Some say that the blame for American aeronautical backwardness lay in the patent wars that the Wrights initiated in 1909 and followed through to a successful conclusion in 1914. There is no doubt that the Wrights' claims to a percentage of every airplane that flew for profit did little to encourage aeronautical innovation in the United States. From any point of view, the Wrights' insistence that they had invented and

The French demonstrated their passion for things that fly at the Exposition of Aerial Locomotion, held in Paris in 1909.

therefore owned the airplane was a huge, even tragic mistake, which in many quarters permanently negated the goodwill they had won by their flights of 1908-1909 and—perhaps more critically—distracted the Wrights themselves from more productive tasks. In effect, by 1910 the Wrights had ceased to be an important factor in aeronautical technology.

But the difference between the two countries' rate of progress was due not so much to the mistakes or defeats of the Wrights as to the different worlds in which the French and the Americans moved. The United States was the ideal setting for the appearance of men like the Wrights—solitary, stubborn, contrary, and brimming with confidence in their ability to solve a problem that had defied the world's best scientists and engineers. They followed in the footsteps of a series of talented independent inventors, of whom Thomas Edison was the exemplar. But it was the French who possessed the elements necessary for the development of the airplane in the years before the first world war.

The French had behind them a tradition of aeronautical innovation that reached back to the late 18th century, when the first balloon flights were made. In the 19th century ballooning flourished as an upper-class sport; in addition, France, along with Germany, was in the forefront of dirigible technology. A decade before the Wrights had gone to Kitty Hawk, a Frenchman, Clément Ader, raised his steam-powered *Eole* inches above the ground—or so witnesses claimed. All this gave the French a prerogative in flight that they had no intention of yielding to other nations.

France also possessed a community of wealthy investors and industrialists, like oil magnate Henry Deutsch de la Meurthe and André Michelin, who were dedicated to the development of aviation. These patrons were clustered around the Aéro-Club de France, an organization that could focus their efforts. They realized that progress required financial incentives, and they opened their purses accordingly. In 1908-1909, for example, French pilots won $200,000 in prize money, most of it contributed by French patrons. By 1914, the Aéro-Club was offering prizes worth $500,000, a princely sum for the period.

By themselves, patrons, no matter how generous, could have done little to promote the cause of aviation. But France also had a critical mass of talented aircraft designers, many of them scientifically trained. At the first international aircraft exhibition, staged in Paris in September 1909, 318 of the 333 exhibitors were French.

It is difficult to see what the French aviators had in common other than their passion for flight and their willingness to sacrifice life, limb, and fortune to achieve it. Louis Blériot, a graduate of one of France's leading engineering schools, was an entrepreneur who had prospered by selling automobile headlights and accessories. A family man with conservative political views, an oval face, a drooping walrus mustache, and a sometimes surly manner, he seemed the essence of the French bourgeoisie. His former collaborator, Gabriel Voisin, was a polar opposite. A one-time student at the Faculty of Fine Arts at Lyon with a substantial inheritance, he seemed to be more interested in his models than his paintings, and the flying machines he designed resembled box kites rather than streamlined birds. Robert Esnault-Pelterie, the organizer of the 1909 exhibit, was the son of a wealthy textile manufacturer and held a degree in physics. He combined financial means and Parisian connections with a sound technical background. Henri Farman had studied painting at the Ecole des Beaux-Arts in Paris before abandoning the arts in favor of auto racing, flying, and eventually the manufacture of airplanes. Because of his mechanical and business talents, he was one of the few early pilots who made the transition to aircraft construction and later to the organization of an air-

By 1914, France's lead in aircraft development had slackened. In Russia, Sikorsky was building big bombers (left), and in England, Sopwith had created a seaplane (below) that would give rise to the Sopwith Camel. In 1927, an American again showed the French how to fly (right).

line. Louis Breguet was the scion of a family of entrepreneurs with a longstanding interest in technical innovation. Once he abandoned an attempt to design a helicopter, he quickly built an aviation empire with profits made from the first world war.

It's a motley crew that escapes any easy generalization. Yet one thing these young men shared was access to a pool of skilled laborers, many of them trained in shipbuilding. The construction of aircraft during the years before 1914 was not an industry in the way we use the term today; it was a craft, or, more accurately, an art. The word used to designate the first aviation factories was *atelier*, the same word used to denote an artist's studio. Picture a small shop with a dozen or so employees working with wood, cloth, wire, iron, and varnish. Remember, too, that before World War I France was famous for its artisans, a highly trained labor force used to working long hours on exacting tasks. The atmosphere in these shops was more that of a family than a factory, with the owner sometimes working alongside his workers. This combination of inspired and driven designers and experienced artisans launched the world's first aeronautical industry.

France's primacy in aviation also depended on a group of outstanding pilots. The early inventors and designers flew their own aircraft, but they were soon supplanted by men (and a few women) who specialized in operating the machines. By January 1911, the number of licensed pilots in France exceeded that of any other country: 555 to 57 in England, 46 in Germany, and 26 in the United States. That year French pilots won every major European aviation race, flying French machines with French engines. The French also paid the price for their leadership in aviation: Of 30 airmen killed in the first six months of 1911, 16 were French. In the Circuit of Europe, a three-week race run in the summer of 1911, three French pilots died, one incinerated in his Blériot. These losses were so keenly felt that France's most famous poet and playwright at the time, Edmond Rostand, felt compelled in July 1911 to justify them in a long poem entitled "The Hymn of the Wing," assuring readers that the French had showed "profound strength" by taking so avidly to the skies. They could only be compared, Rostand said, to the ancient Hellenes who had heroically given their lives for Greece.

Aviation in France quickly took on an unmistakably national character, inspired by the likelihood of war with Germany. Germany had its army, the most powerful in Europe, and Britain had its navy, with which it ruled the waves and extended its power throughout the world's oceans. With a stagnating population and limited resources, France could not duplicate these forces. But through the prowess of its pilots, the country could now hope to dominate the air.

The French public's wildly enthusiastic support of aviation was by no means inspired solely by aviation's novelty and excitement as a sport. As the nationalist writer René Bazin explained in 1912

after the Circuit of Anjou race, which was won by French aviator Roland Garros, the French didn't applaud their aviators simply because they performed daredevil acts of heroism and competed for prizes. They applauded them because they risked their lives for *la France.* "Because of that, when you [aviators] appear, all of France is moved," wrote Bazin. "And it loves you, it applauds you, it thanks you, because in you, who are fearless, it rediscovers the knights who made it what it is, a vanguard nation, elegant in the face of peril." Indeed, a poll taken in 1909 of French secondary students revealed that respondents admired aviators more than any other historical or contemporary personalities. Blériot, the conqueror of the English Channel, was more popular among them than Napoleon.

Still, the aviation madness of the crowds who flocked to airshows and races would have counted for little if the French government had not responded by investing large sums of money in the purchase of airplanes, nourishing an aviation industry that could never have survived on private purchases. Fortunes could be made by the designers and manufacturers who won government contracts. Between 1909 and 1912, as the French sensed a growing menace in Germany, the amount of money the government spent on aircraft more than tripled. It would almost double again during the next two years, an indication of how keenly the threat of war was felt.


EXTRA ★ St. Paul Daily News ★ SPORTS COMPLETE N.Y. STOCKS

LINDBERGH IS IN PARIS

FLIER COMPLETES AIR DASH FROM NEW YORK

Flight Sends Wright Stock Up 5 Points

HERE'S PARIS FLIGHT LOG

SPIRIT OF ADVENTURE

Los Angeles Off On Trial Cruise

Hence the attraction that aviation exerted on entrepreneurs and capitalists in pre-1914 France. Take the case of the Belgian-born Armand Deperdussin. A former cabaret singer who with borrowed money had made a fortune selling imported silk to big department stores, Deperdussin entered the aviation business in 1910 in the aftermath of Blériot's Channel flight and the great airshow at Rheims. Though innocent of any technical training, Deperdussin knew talent when he saw it and was shrewd enough to hire Louis Béchereau. In 1913 the young engineer designed for him the most advanced racing airplane of the pre-war years, a monoplane of revolutionary monocoque construction that delivered structural strength in its skin, like an eggshell, and required no internal bracing or external birdcages of struts and wires. It was covered with three-ply sheets of tulip wood and varnished cloth to enhance its streamlined aerodynamic characteristics and was powered by a 140-horsepower Gnome rotary engine. Deperdussin's firm won handsome contracts from the French government and had even begun to penetrate the Russian market when its fast-living and free-spending owner was charged with forgery, fraud, and breach of trust. Not even the outbreak of war could save Deperdussin from disgrace, although a reorganized version of his company controlled by his rival Blériot went on with designer Béchereau to produce one of the most famous fighters of World War I, the SPAD VII. Deperdussin's career—and that of others—suggests the volatility of an industry that depended for its survival on the largesse (and fears) of the French state.

At the beginning of 1913, the French domination of the air was unquestioned. There was scarcely a record that the French did not own. In the course of the year, however, European and American rivals began to close the gap that separated them from the "winged nation," as France called itself. In Britain, Thomas Sopwith developed the Tabloid seaplane, which would win the Schneider Trophy in April 1914 and go on to serve as the prototype of the most successful fighter of World War I, the Sopwith Camel. In Russia, Igor Sikorsky took the lead in the design of large multi-engine airplanes capable of transporting large numbers of passengers and, later, heavy bomb loads. In the United States, Glenn Curtiss, undeterred by the Wrights' patent suits against him, had succeeded in designing an airplane capable of operating from a ship.

Many talented European and Russian designers—among them Sikorsky, Anthony Fokker, Alexander de Seversky, and Giuseppe Bellanca—would eventually make their way to the United States, which offered greater opportunities for the development of commercial aviation because of its huge and growing population, the enormous distances between its major cities, and the ready availability of venture capital, especially after World War I. France would struggle to maintain the appearance of aeronautical primacy during the early 1920s, nervously looking over its shoulder at its European rivals. But the truth was that the baton of aeronautical progress had long ago passed to other hands.

Charles Lindbergh's 1927 flight from New York to Paris in an American monoplane with an American engine and instruments, coming so quickly on the heels of the disappearance of French aces Charles Nungesser and François Coli in a biplane over the North Atlantic, served as a bitter reminder to the French that the age of aviation had begun at Kitty Hawk. Once more an American had taught the French to fly.

For more information about French aviation in 1913, browse the Web at www.airspacemag.com/10th/1913.html

Across the Atlantic

Lindbergh did it on his own years earlier, so why did entire airlines have so much trouble following in his footsteps?

SHORT BROTHERS, INC.

by Henry Scammell *Paintings by Ken Dallison*

In the first third of the 20th century, transatlantic travel was the equal of a term in prison. Although the sentence had been shortened by the rise of steam power a century before, and the squalor of the early packets had been replaced (for those who could afford it) by the elegance of the oceanliner's grand salon, the one-way journey usually took at least a week, and the expense made it, for many, the commitment of a lifetime.

Nearly 800,000 passengers made that commitment in 1937. They didn't have much choice. In May, the German *Hindenburg* airship exploded, ending the world's only transatlantic air service.

But only weeks later, the British and the Americans embarked on a series of survey flights that would tantalize the world with the most dramatic demonstration of the future of transatlantic travel since Charles Lindbergh's daring solo 10 years before.

The contestants—for the surveys were, unofficially, a kind of contest—rode in gleaming metal flying boats, each representing the apex of its nation's aviation technology. With all the ritual of tournament, the contenders, painted in the liveries of Pan American and Imperial Airways, rose from their watery lists and tilted synchronously past each other above the ocean waves.

These were the first airline flights ever made across the North Atlantic. Neither aircraft carried a significant payload, but the message they bore was a potent one: Commercial airplane flights across the Atlantic were on the horizon.

The name usually associated with opening up transatlantic air travel is Charles Lindbergh, but though he was the first to make the journey alone, others had preceded him. In 1919 three U.S. Navy flying boats took off from Trepassey Bay in Newfoundland and headed toward Plymouth, England. Number NC-4, piloted by A.C. Read, managed to com-

In 1937 two flying boats—Pan American's S-42B (left) and Imperial Airways' S.23 (above)—completed pioneering surveys of transatlantic routes. But when it came to providing regular commercial service across the ocean, neither airliner proved up to the challenge.

plete the 2,775-mile journey, hopscotching along a circuitous line of warships to make the first transatlantic crossing by airplane. (Of the other flying boats making the attempt, one became the first airplane to sink in the Atlantic and the other was damaged by a wave and ended its flight in the Azores, islands about 1,300 miles west of Portugal.)

The man who dispatched the NC-4 from Trepassey Bay was Powers Symington, a young Naval officer from a prominent family in Baltimore. Symington's nephew, Fife Jr., now 86, recalls his family's close involvement in the early days of transatlantic flight. "When I was home from Kent School at 16 and 17," he says, "I often sat in our library at Tallwood in Baltimore while my Uncle John [Hambleton] and Juan Trippe and Sonny Whitney told my parents about their plans" to start a transoceanic air service. "My father was a civil engineer, but he had been associated with Hambleton and Company as an investment banker, so he knew the right questions and was pretty good at judging the answers."

PAN AM HISTORICAL FOUNDATION

Igor Sikorsky's S-40 amphibian was the first Pan Am aircraft to bear the name "Clipper," which Juan Trippe chose to evoke the American clipper ships that once bridged the oceans.

Aviation history traditionally credits Trippe, a banker's son, with the dream of transoceanic air service. But according to Symington, the vision was not Trippe's alone. "Even before Lindbergh made his flight, Johnny and Juan were forming their own plans for commercial transatlantic aviation," he recalls, "and my father was especially interested in Johnny's claim that airliners would someday fly across the poles; in those days it was like saying we'd someday reach the moon. Trippe supported him in this, but that part of the vision was clearly Johnny's own.

"When I listened to them, even though the ideas were fantastic they sounded credible," Symington adds. "Johnny had been an aviation hero in the war, and now he was the shining hope of the coming era of flight." (If Hambleton's greatest asset was his vision, a strong second was his physical presence: He had strong good looks and the lanky, athletic build of a pilot.)

In due course, the young visionaries persuaded some of the biggest family names in American finance to help back the formation of an airline. Trippe assembled a board that included Yale classmates William Rockefeller, Bill Vanderbilt, and Cornelius ("Sonny") Whitney—and of course John Hambleton, a Harvard man. In 1927, after deals with several early airlines had met with varying degrees of success, Trippe and his backers gained control of an outfit called Pan American Airways, which had a contract to deliver mail between Key West and Havana.

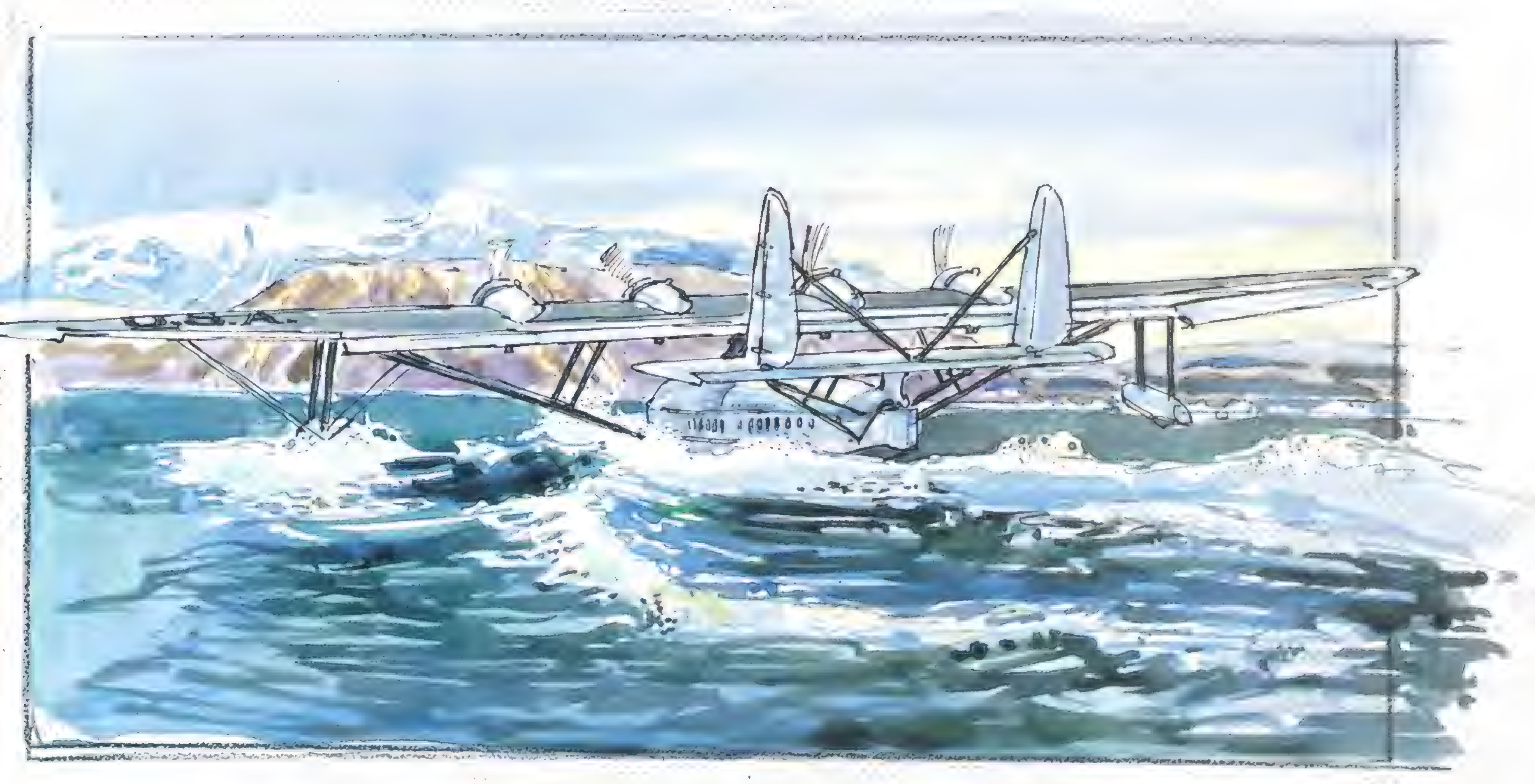
Infused with capital, the airline quickly set to work on the problem of transoceanic flight. In 1928 alone, Pan American workers developed radio technology for aircraft, ground aviation direction finders, emergency fuel dump valves, air traffic control systems, and emergency exits.

That summer, Trippe got a call from Charles Lindbergh, whom he had met before the Lone Eagle's New York-to-Paris flight. After they talked, Lindbergh agreed to launch a series of promotional tours, surveys, and proving flights that would open routes for the embryonic airline across the Gulf of Mexico and into the Caribbean. One such flight, scheduled for early February 1929, would open mail service from Miami to Cristobal in the Panama Canal Zone, and required flying into places where information on landing sites was scant. Acutely aware of the enormous symbolic value of Lindbergh's name, Pan American's management decided it must minimize risk to its new trailblazer, so a week before the scheduled survey, John Hambleton secretly flew a Sikorsky S-38 amphibian over the course, noting obstacles and hazards. When the flight was repeated for public consumption, Hambleton was aboard again, identified in news stories as "Colonel Lindbergh's mechanic."

"At Pan American," Lindbergh wrote shortly before his death in 1974, "we never forgot that flying the Caribbean was a step toward flying the Atlantic and Pacific." That early flight to Panama was a long way from crossing the Atlantic, but it was as far as Pan American's co-founder was to travel in the quest to realize his transoceanic dreams. On June 6, 1929, John Hambleton died in a crash near Wilmington, North Carolina, a passenger on someone else's airplane. He was 29.

Now Trippe would have to meet the transoceanic challenge without the benefit of his friend's counsel and vision. Fortunately, in addition to being as persuasive as Hambleton, Trippe was extraordinarily persistent in negotiation and had an unsurpassed instinct for the business side of flying.

Unlike the aptly named Pacific, the Atlantic Ocean had a reputation for ferocity. The North Atlantic's more souther-



ly routes were long enough to tax most aircraft, while the northern routes, though considerably shorter, posed the greatest risk of fog, icing, and sudden, unpredictable change. In fog or clouds, a pilot had no way to maintain the horizon and could easily lose control of his aircraft before even being aware of trouble. When the French airline Aéropostale began setting up a transatlantic mail delivery service in the early 1930s, it avoided the daunting North Atlantic altogether, choosing instead to develop routes between Africa and South America.

In 1933 Pan American had Lindbergh survey the far reaches of the North Atlantic. Setting out from Flushing Bay, New York, Lindbergh and his wife Anne flew to the eastern end of Newfoundland, turned northwest to explore the coast of Labrador, then flew on to Greenland, Iceland, the Faroe and Shetland Islands, Scandinavia, and finally Russia. The trip, Lindbergh later wrote, "left no doubt in my mind about the wisdom of establishing the first air route to Europe by way of Bermuda and the Azores. Ice conditions along a more northern route would prevent operation of flying boats [during the winter]…we could never give satisfactory service to transatlantic passengers if we had to move our terminal with the seasons."

And what worked in the Pacific wouldn't necessarily solve the problems of the Atlantic. In 1935 Pan American was able to open trans-Pacific service with the all-metal Martin M-130 flying boat, but even against the relatively light winds of the Pacific, the M-130 could carry only nine passengers from San Francisco to Honolulu. In both range and efficiency, the M-130 would never be able to meet the challenge of the Atlantic with a viable payload.

The Germans tried to meet the challenge with a gigantic 12-engine flying boat called the Dornier Do-X. In 1931 the craft made a staged crossing of the South Atlantic, but it was grounded several times along the way for repairs, it guzzled 400 gallons of fuel an hour, and even after it had been lightened as much as possible, on the 1,500-mile stretch between the Cape Verde Islands and South America, it couldn't get much more than 20 feet above the waves. The Germans had better luck with schemes entailing more modest fuel requirements. In the 1930s the German airline Deutsche Lufthansa established airmail service between Europe and South America with a sort of relay-race setup in which a series of Dornier seaplanes were launched from catapults on depot ships stationed across the South Atlantic (see "Germany's Atlantic Air Bridge," June/July 1992).

Air transport pioneers came up with an ambitious varia-

Charles Lindbergh complained that piloting the S-40, with all its struts and wires, was like "flying a forest," so Sikorsky designed the S-42 (above) with streamlined wing, turret, and hull to minimize resistance.

When Lindbergh (below, in helmet) and John Hambleton (bending) returned from Pan Am's first delivery of mail to Panama, newspapers reported that Hambleton had served as the Lone Eagle's mechanic. In fact he had flown as copilot.

COURTESY GEORGE HAMBLETON

FOYNES FLYING BOAT MUSEUM

S.23 flying boats like the Caledonia *weren't up to the transAtlantic challenge, so British designer R.H. Mayo devised an alternative: A flying boat would ferry a mail-carrying floatplane partway across the Atlantic (opposite) and then release it, thereby reducing the smaller craft's need for fuel.*

tion of the sea launch concept: floating airports to be tethered at intervals across the oceans, complete with refueling stations, communications and repair facilities, and even hotels (see "Fantasy Islands," Oldies & Oddities, Apr./May 1993). But such structures would be vastly expensive and vulnerable to ocean storms. They never got beyond a model test.

Another solution to the problem of transoceanic distances was to fly the fuel to the airplane rather than vice versa. Aerial refueling had been demonstrated as early as 1923, and the idea kept cropping up through the next two decades. But as the technique evolved, it was restricted almost exclusively to cargo and military aircraft, probably because it was perceived as overly risky for passenger flights.

Dirigibles didn't pose range problems, but when Lindbergh looked into them for Pan American in the early 1930s, he found them "too awkward, too slow, too vulnerable to ground and storm gusts." For a time the Germans harbored lighter-than-air dreams of Atlantic supremacy, but they lost interest when their *Hindenburg*, which began providing passenger service between Frankfurt and New Jersey in 1936, exploded the following year. For the moment, the most reasonable candidates for transoceanic flight appeared to be flying boats.

Lindbergh believed that the era of the flying boat would be brief—that with improved navigation and increased range, altitude, and speed, world aviation would be dominated by landplanes. But for most of the 1930s, commercial transoceanic service by landplanes was not realistic. For one thing, with the threat of forced landings looming over the early flights, sea-based aircraft were simply considered safer. But a bigger problem was the lack of airports.

A small airplane like *The Spirit of St. Louis* could take off and land on almost any large, flat, open field, but under the weight of a flying machine big enough to carry a group of passengers across the ocean, the grass runway at Le Bourget would have proven about as solid as a bog. Ten years later the situation had barely changed. In America, New York's Floyd Bennett Field was the only paved landing area on the east coast; the next nearest was Ford's field in Dearborn, 10 miles west of Detroit. And in all of Europe, there were only five hard-surface strips.

Paved airports were enormously expensive, and with America's initial commitment to flying boats for transoceanic flight, no company had built enough big land transports to warrant the investment. Then, too, Germany was working on the most advanced long-range commercial landplane of the era: the Focke-Wulf Condor, which in 1938 would make a dramatic round-trip transatlantic crossing with two full crews. President Franklin Roosevelt didn't want to improve Germany's competitive advantage by rolling out a cement welcome mat.

On his two longest survey flights for Pan American—the northern Pacific Rim in 1931 and the North Atlantic in 1933—Lindbergh flew a Lockheed Sirius floatplane (christened *Tingmissartoq*, it's now on permanent display at the National Air and Space Museum). After the first survey, the Sirius was given a more powerful Cyclone engine, larger fuel tanks, a new two-pitch Hamilton Standard propeller, and the latest Sperry gyroscope, a heading indicator that was more stable than a compass during turns. Nonetheless, the 1933 flight confirmed Lindbergh's judgment about the superiority of landplanes. The pilot had planned to return to Newfoundland via the Azores, but when he could find no harbors there

big enough for the long takeoff required by the weight of his extra fuel, he turned southeast to Africa. In Gambia he had a similar problem. "Without wind or wave chop, I was unable to get our pontoons up 'on their steps,' " he wrote in his book *Autobiography of Values*. Finally, after stripping out every last pound of unnecessary weight, he was able, with the help of a light wind, to break free. "I concluded that landplanes would eventually replace flying boats wherever airports could be built within practical range of one another," he wrote.

Until then, for experimental sorties over the Atlantic, Pan American came to depend on Sikorsky S-42 flying boats. The S-42 had been conceived in conversations between Lindbergh and airplane designer Igor Sikorsky on the return leg of the inaugural flight of an earlier Sikorsky flying boat, the S-40, to Panama in 1931. "I objected to the awkwardness of the [S-40] design," Lindbergh wrote later, "and said bluntly that it [was] like flying a forest through the air." Sikorsky replied, "I agree with you, Co-ro-nel, the resistance is high. But to remove it is still another step."

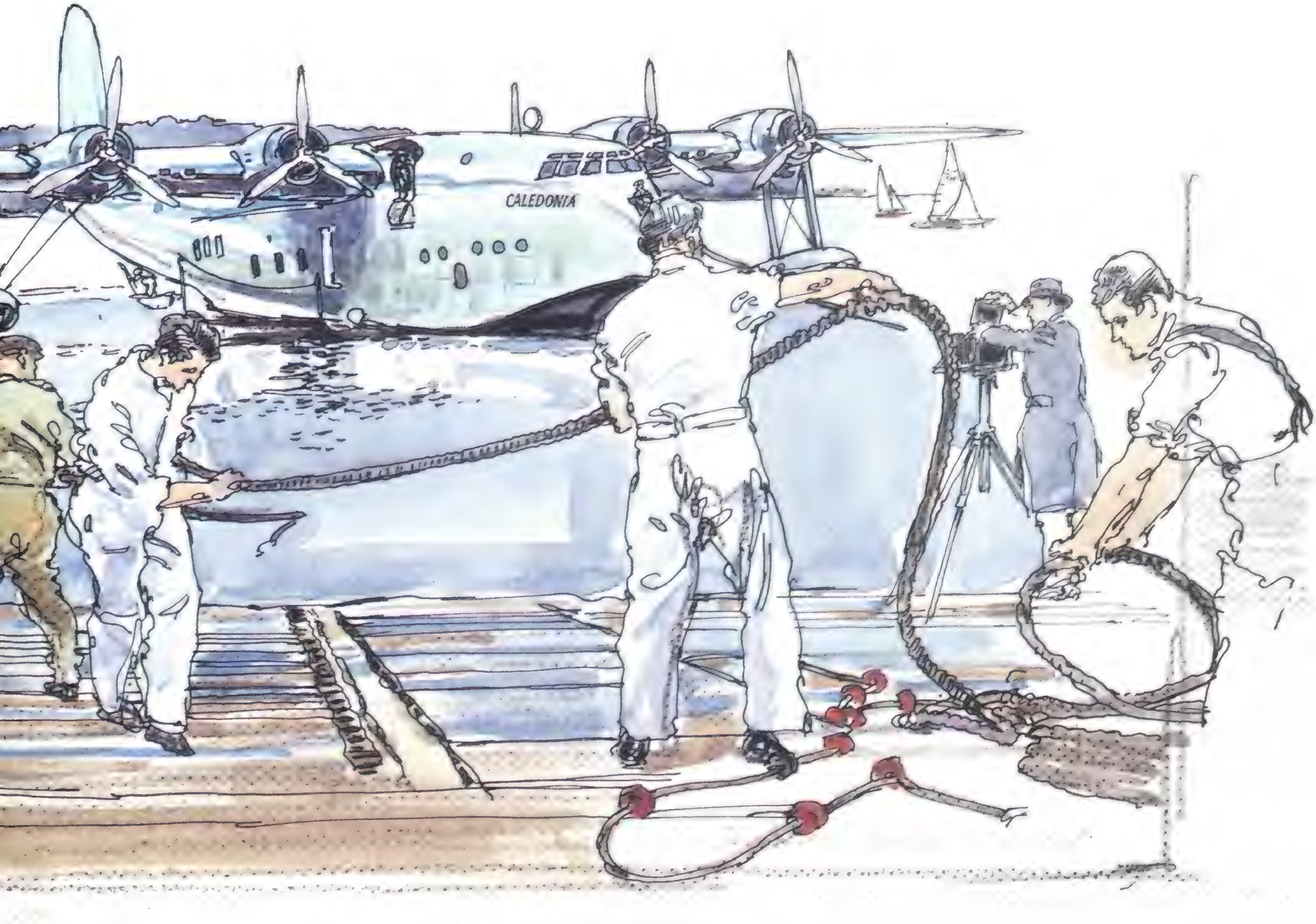
The S-42 was that step. The new idea was such a radical departure from previous designs that it would be uncertifiable under the then-prevailing civil aeronautics regulations limiting landing speeds to 65 mph and an aircraft's total weight to 15 pounds for every square foot of its wings. The

NASM

Department of Commerce's rules on wing loading were safety limits, based on the properties of the wood and fabric with which wings were initially constructed. If those properties could be improved with new materials and new techniques of engineering, the commerce department might be persuaded to raise the weight limits.

"Intuitively, they both knew that if they could get this higher wing loading, cruise speeds would go up and gust responses would decline, greatly improving efficiency and passenger comfort," recalls Igor Sikorsky's son Serge.

The result was impressive enough to persuade the com-



merce department to change its rules. Delivered in 1934, the S-42 had a wing loading of 29 pounds, nearly double the prior commercial standard. In addition, the wing profile incorporated a far more efficient new airfoil with extraordinarily high lift, low drag, and stability regardless of the airplane's attitude through the different regimes of flight. And the S-42 was one of the first commercial aircraft with landing flaps to be certified flightworthy. When lowered to two or three degrees the flaps increased the camber—the airfoil's curvature—which meant more lift; when dropped to a 35- to 40-degree angle, they reduced airspeed for the final approach.

The overall design of the S-42 incorporated new principles of streamlining in the wing, turret, and hull to minimize resistance. These features were combined with new Pratt & Whitney 750-horsepower Hornet engines and the first commercial application of Hamilton Standard's variable-pitch propellers, which could be adjusted for the different demands of takeoff, cruising, and landing. The S-42 also used cruise control, which increased the efficiency of fuel consumption by matching engine speed to the steady decrease in gross weight over the course of a flight.

On August 1, 1934, Lindbergh, Pan American chief pilot Ed Musick, and Sikorsky chief test pilot Boris Sergievsky made the formal acceptance flight of the S-42 for Pan Am. They took off from the Sikorsky plant in Stratford, Connecticut. Taking turns at the controls, the three flew a course to New Jersey, over Staten Island and Long Island up to Rhode Island, and then back to the Sikorsky plant. They flew the course four times, for a total of 1,242 miles nonstop—significantly, two miles longer than the distance between North America's Newfoundland and Europe's Azores.

But not until three years later would the S-42 take the final step.

In 1937, the British-American seesaw between trade rivalry and political accommodation, in motion long before the birth of powered flight, was suspended in a state of artificial balance to allow Pan American and Britain's Imperial Airways to conduct two series of survey flights. The first series began almost exactly 10 years after Lindbergh's solo crossing. On May 24, an Imperial S.23 flying boat and a Pan American S-42B took off simultaneously from opposite ends of the 800-mile route between Port Washington on Long Island and Hamilton Harbor, Bermuda. A "square deal" agreement engineered by Britain required the rival aircraft to land at the same time as well, but for that to happen the race had to be rigged. The S.23, shipped to Bermuda straight off the Short Brothers production line in Kent, was newer than the S-42B, but it had a much shorter range. It was also handicapped by prevailing winds that favored the "downhill" passage from west to east. So while the British entry was laboring ponderously toward Long Island, the American competitor, already at the end of its journey, loitered gracefully and perhaps a bit pointedly over Hamilton Harbor long enough to create the illusion of a tie.

Six weeks later, the competitors faced off again, this time across the ultimate playing field.

On July 5, veteran Pan American flying boat captain Harold Gray and a crew of six took off in the S-42B *Clipper III* across the iceberg-dotted waters of Botwood, Newfoundland, heading east to Foynes Island in Ireland and ultimately to Southampton, England. Again simultaneously, Imperial Airways captain A. S. Wilcockson slipped the mooring of the S.23 *Caledonia* at Foynes on the Shannon, pointed the flying boat into a 30-mph westerly headwind, and roared down the path of the lowering summer sun.

PAN AM HISTORICAL FOUNDATION

Gray later recalled: "We contacted several ships on the way over and passed *Caledonia* at longitude 30° West about 4:15 a.m. At that time the machines were 60 miles apart.... [O]ur exchange of messages was of a routine character and I described the weather which we had encountered and he passed over information regarding the weather he had left behind." Periodic reports on the two flights were also radioed to enormous audiences on both sides of the ocean. Hours ahead of the expected arrivals, crowds began to collect at the destinations.

Twelve and a half hours after takeoff, Gray, favored by the prevailing winds, landed at Foynes. One prescient witness likened the event to "a messenger boy arriving on a bicycle." Gray's counterpart arrived at Newfoundland two and a half hours later.

The S-42B would fly two more surveys to England in 1937, the final one to test the southern route through Lisbon and Marseille via Pan American's new landing concession in the Azores. "The S-42B was wonderful for survey flights," remembers John Borger, who was on hand for Pan American's initial crossings of both oceans. "It carried some mail [to England in 1937], and on the first survey flight there it carried some 1,900 pounds of spare parts, so to that extent it had a payload."

Like Imperial's S.23, Pan American's S-42B was deemed capable of providing regular passenger service between New York and Bermuda, starting just weeks after its survey of that route. But, says Borger, "it just couldn't fly all the way across the Atlantic with passengers. The airplane was certi-

The photograph above, taken around the time Pan Am introduced transatlantic service with the Boeing 314 (opposite), was clearly meant to convey Trippe's confidence in his airline's ability to conquer air routes around the world.

To learn more about early transatlantic flight, browse the Web at www.airspacemag.com/10th/1937.html

fied for a maximum gross weight at takeoff, and with the fuel requirements of the Atlantic, we couldn't add significantly to our weight and meet airworthiness regulations."

Still, the S-42 was enough to hold America's place in the race. Until 1937 the British had stalled on the issuance of landing rights, not just in England but in Newfoundland and Bermuda as well, while they tried to develop an airplane of their own equal to the transatlantic challenge. (Pan Am faced fewer such complications in the Pacific because all of the staging points there were U.S. territories.) As to how well the British had succeeded, Borger, who at the time of the first transatlantic survey was assistant to the Pan Am division engineer in Port Washington, recalls checking out the *Caledonia* after it landed. "It was stripped absolutely clean," he says, "with just a bare catwalk down the cabin. They had a crew of four, while we had a crew of seven or eight. It was obvious they just didn't have an airplane. And that's what it was all about. All of the big challenges in flying the oceans, such as weather, distance, landing sites, fueling, communication, navigation, what-

ever, came down to that one thing."

The British had one other card up their sleeves. That year designer R.H. Mayo developed a piggyback arrangement whereby a modified four-engine Short Empire flying boat, the *Maia*, carried aloft a smaller twin-engine floatplane, the *Mercury*. The *Maia* would fly the *Mercury* out over the sea and release it, sparing the floatplane the effort of trying to take off conventionally while loaded down with payload and fuel. But though the composite worked well in trials, it was deemed fit only for mail flights.

By this point the British most likely realized that the race was lost. The next generation of American flying boats, the Boeing 314, was already in production, with a fantastic maximum gross takeoff weight of 82,000 pounds and a range of 3,500 statute miles. When Pan Am's 314 Clippers finally began providing regular transatlantic passenger and airmail service in 1939, they would own the ocean.

Some of the most important innovations that opened the oceans for Pan American were not just in the basic aircraft design or the power of the engines but in a variety of instrumentation and support systems. Two of the principal ones were the Sperry gyro and artificial horizons, which showed attitude when there were no outside references such as when flying at night, in clouds, or in heavy fog.

COURTESY FIFE SYMINGTON JR

The list of factors contributing to Pan American's rise and dominance in transatlantic flight wouldn't be complete without mention of André Priester, the little bald Dutch martinet who joined the airline at its start and became one of the most respected—and feared—figures in American aviation. Under Priester, every pilot who went to work for Pan American started off on the hangar floor and only graduated to flying after learning the business from the ground up. If he expected to stay in the cockpit he was required to take endless correspondence courses, becoming expert in flight engineering, over-water navigation, communications, and other disciplines, until finally he was awarded the highest possible honor Priester could bestow, the title of Master Ocean Pilot. "Modern pilots would say we were far overtrained," says former Pan Am chief pilot Paul Roitsch, "but those were different times. If airplanes had begun to crash every few days, the commercial aviation industry would have simply collapsed."

One who profited from Priester's lessons was recent Princeton graduate Fife Symington Jr. A dozen years after listening to his Uncle John Hambleton's thrilling visions of flying vast distances, he had gone to work for Pan American, where he was trained not just by Priester but by Juan Trippe as well.

Like other applicants for junior executive positions, Symington had been encouraged to take a trip "over the line"—along one of the airline's routes—at his own expense and report on it to the Pan American leadership. After his flying boat tour, Symington produced a long, erudite, insightful tome entitled *Observations on Commercial Aviation in Latin America, Fall, 1934*. Trippe gave him a grade of 99 percent and sent him to the Glenn Martin factory in Baltimore to learn how airplanes were built. Symington went on to serve terms in Brazil and Argentina, returning to Baltimore in time to sell tickets on the early flights to Bermuda. When Pan Am set up business in London and commercial transatlantic aviation at last became a reality in 1939, he would be there as well, a witness to the great adventure that John Hambleton, Juan Trippe, Cornelius Whitney, Charles Lindbergh, and thousands of others had helped to set in motion.

The 314's first passenger-carrying flight across the North Atlantic landed in Southampton, England, in April 1939 (above); today, Fife Symington recalls accompanying the passengers on to London by train. The majestic 314 featured posh touches reminiscent of luxury oceanliners, such as a dining room, sleeping berths, and even dressing rooms.

B-36: BOMBER AT THE

by Daniel Ford

In 1947 the United States Air Force became an independent service, carved from the Army and placed under the control of the newly created National Military Establishment. The new service faced daunting challenges. There was the threat from a new adversary, the Soviet Union. But there were challenges at home as well: from the Navy, which viewed those in the new uniforms as rivals for diminishing defense funds; and from within, as the Air Force struggled to introduce jet-powered aircraft into operational service.

In the spring of 1949, the country got a new secretary of defense: Louis Johnson, a wealthy lawyer, aspiring politician, and former official with the Convair Corporation, which was a longtime supplier of U.S. military aircraft. That last connection, which today would seem a scandal worthy of a special prosecutor, was common at the time. Who knew more about weapons than the men who built them?

When President Harry Truman ordered Johnson to economize, he obliged in April by canceling the 65,000-ton super-carrier *United States*, the keel of which had been laid only a week before. But the carrier was the linchpin of the Navy's plan to equip itself for the strategic nuclear mission. Carrying aircraft able to deliver atomic bombs to a target 1,000 miles away, the *United States* would have projected naval air power across the world's oceans, just the mission the Air Force wanted for its land-based bombers. Johnson's order, though only two sentences long, set off an interservice squabble the likes of which the nation had rarely seen.

Relations between the Army and Navy had first soured in the 1920s over which service should defend the U.S. coast, and World War II had only sharpened their rivalry. Now the Navy viewed the postwar creation of the Air Force and the Department of Defense as twin political threats to its primacy as the defender of U.S. shores. The spat that followed cancellation of the *United States* became known as "the revolt of the admirals," and it pitted the Navy's aircraft carrier against the Air Force's strategic bombing force—more specifically, Convair's monster six-engine bomber, the B-36, which had entered service in the summer of 1948.

Now it was a year later, and matters were coming to a head. The first shot in the battle was fired by Cedric Worth, a civilian assistant to Navy Undersecretary Dan Kimball for "special study and research," as he later described his duties under oath. It came in the form of a nine-page memo for the Navy's internal use (though he admitted giving copies to three members of Congress and to aircraft manufacturer Glenn Martin). The document condemned the B-36 as "an obsolete and unsuccessful aircraft" and charged that the Air Force had acquired it only after Convair had contributed $6.5 million to various Democratic politicians.

The theme was picked up by the Navy League, which spent $500,000 trashing

PHOTOGRAPHS COURTESY NASM

These B-36s overflew Harry Truman's inauguration, but their rumble drew more attention in Congress.

CROSSROADS

It was the biggest warplane ever to wear an American star, and in the summer of '49, the Peacemaker found itself a war—in Washington.

the mega-bomber. (That amount, at least, was the estimate of the rival Air Force Association. If these sums don't seem exciting, consider that in 1949, the minimum wage in the aircraft industry was 50 cents an hour.) The B-36 was described as a "lumbering cow" and a "billion-dollar blunder," and the Navy claimed it had at least three jet fighters that could leave the monster behind at 40,000 feet. The admirals wanted a matchup, but they would never get one.

The Joint Chiefs of Staff told Johnson the test was a bad idea. And the Air Force said it had already demonstrated that fighters couldn't *maneuver* at that altitude. Simulated B-36 attacks on bases in Florida and California were met by three front-line fighters: a North American F-86A Sabre, a Lockheed F-80C Shooting Star, and a Republic F-84 Thunderjet. Radar picked up the intruder 30 minutes out; the fighters took 26 minutes to climb to 40,000 feet and another two minutes to find the B-36. The fighters were faster than the big bomber, but their wing loading (the ratio of aircraft weight to area of the wings) was so high that they couldn't turn with the bomber without stalling in the thin air. Even if a B-36 were detected and Soviet fighters caught it, the pilot could evade them by making S-turns, said the Air Force.

Of course, the Russians wouldn't have been flying USAF jets, as British engineer Harold Saxon argued in an edition of *Aviation Week* that appeared in midsummer. While the Americans valued speed and therefore reduced the span and area of their jets' wings, the British built fighters that could maneuver at stratospheric heights, beginning with the de Havilland Vampire, which had been designed for the first British turbojet engine, and which by 1949 had done "a lot of development flying since 1947 between 50,000 and 60,000 feet," according to Saxon.

By early June, the battle had moved into the halls of Congress when James Van Zandt, a Republican Congressman from Pennsylvania and captain in the Navy reserve, took up the charges leaked by Worth's memo. On the House floor, Van Zandt demanded an investigation of the "ugly, disturbing reports" that the bomber project would have been canceled a year ago if not for wheeling and dealing by Louis Johnson, other Convair officials, and Stuart Symington, the civilian head of the Air Force.

Symington, in a speech at Brookline, Massachusetts, had summed up the final judgment on the B-36: The bomber could "take off from bases on this continent, penetrate enemy defenses, destroy any major urban industrial area in the world, and return non-stop to the point of take-off." Symington's claim was preposterous, but it was widely believed. So Congress did what it does best: It scheduled hearings. But they were delayed until August, infuriating Van Zandt, and also broadened into a debate about the strategic roles of the Air Force and Navy. During the dramatic proceedings, a browbeaten Cedric Worth was unmasked as the author of the memo that had incited the ruckus and forced to recant everything. "I think I was wrong," he told the committee.

"You made a grave error, did you not?" he was asked.

"Yes."

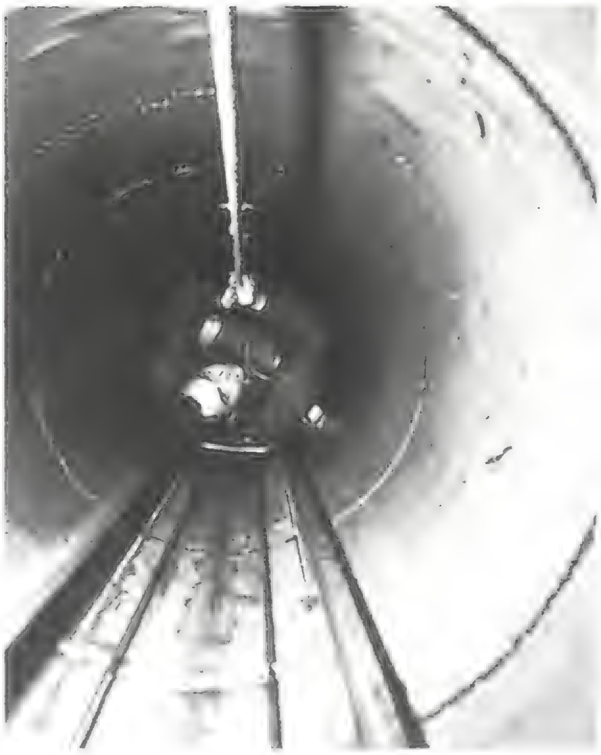
U.S. bombers had been getting steadily bigger, so the enormity of the B-36 may have seemed part of an American pattern, but the bomber actually owed its immense bulk to a succession of hostile dictators, starting with Adolf Hitler. In the spring of 1941, German troops held most of western Europe and seemed likely to conquer Britain next. The U.S. Army asked airframe builders for an airplane that could take off from American soil, bomb Germany, and fly home.

The most promising design came from Consolidated Aircraft in San Diego, builder of the B-24 Liberator, which was just entering service with U.S. and British air forces. Consolidated proposed a quantum leap over the B-17 and B-24 heavy bombers as well as Boeing's next-generation "very heavy" B-29 Superfortress. The B-36 was to be a mega-bomber, spanning 230 feet from wingtip to wingtip. It would cross the Atlantic, enter German airspace at 300 mph, and drop 10,000 pounds of bombs from 40,000 feet, too high for flak or fighters to trouble it. Impressed, the Army ordered a pair of prototypes on November 15, 1941.

Three weeks later, the Japanese attacked Pearl Harbor, and the U.S. suddenly found itself fighting a two-ocean war. The B-36 went on the back burner while Consolidated turned out thousands of its proven Liberators. The B-36 suffered another setback when its facilities were moved to Texas, and yet another when the designers were asked to build a transport based on the bomber.

While Europe was pounded from bases in England, Japan was to be targeted by the Boeing Superfortress flying from China. The Japanese set out to capture the Chinese airfields—and thereby moved the B-36 back to the front burner. From Hawaii, it could bomb Tokyo as it had once been expected to bomb Berlin. In June 1943 the Army asked for 100 copies of the mega-bomber, with the first to arrive in the summer of 1945.

The U.S. Marine Corps moved faster than Convair (Consolidated merged with Vultee in 1943, and the new name was coined then). Shortly after Guam, Saipan, and Tinian were in U.S. hands, the Superforts began their terrible punishment of the Japanese home islands. The Pacific war ended six months earlier than expected—and six days before the rollout of the first B-36, its nose jacked up to lower its tail, which was too tall for the hangar door. It debuted as the Peacemaker, but the name never took, and even today it is better remembered simply as the B-36.



The sheer size of the B-36 was unprecedented. Pressurized crew compartments fore and aft were connected by an 85-foot tunnel (above) traversed by a trolley. The towering tail (below) and 230-foot wings wouldn't clear the hangar door, so Convair workers jacked up the nose and rolled new bombers out of the Fort Worth, Texas plant crab style (opposite).

In a country celebrating peace, the prototype would have been the last of the line, but the Soviet Union turned out to be as land-hungry as Nazi Germany and Imperial Japan. Nonetheless, the U.S. military packed for home in a stand-down so thorough that it was "not a demobilization," as General Leon Johnson noted in a 1954 interview, "it was a rout." The spring of 1946 became a replay of 1941, with a hostile dictator swallowing pieces of Europe and the Americans unable to do anything about it. The "strategic" card—the threat of wholesale destruction by nuclear weapons—seemed the only one that a demobilized, budget-cutting United States could play. But which of the services would play it?

When Congress had created the independent air force in 1947, the new service had been organized around two combat arms: a Tactical Air Command (TAC) to support the ground troops and a Strategic Air Command (SAC) to take the war to the enemy. The Air Force would have a fleet twice the size of the Navy's—24,000 aircraft to 11,500—and only the Air Force would have heavy bombers.

Following the U.S. withdrawal to the continental United States and the emergence of Joseph Stalin's ambitions, SAC's strategic mission was in the ascendant and there was no longer any question who the "enemy" was. By happenstance, the long-distance payload of the B-36 equalled the weight of one atomic bomb—roughly 10,000 pounds—and its combat radius equalled the great-circle route from Maine to Leningrad. Pending the arrival of its new $5.7-million-dollar baby, SAC made do with 160 veteran B-29 Superforts, and it was these aircraft that answered the call to deploy to European bases when the Russians shut off ground access to Berlin in the summer of 1948.

It was a colossal bluff. In all of SAC, only 27 Superforts had the "Silver Plate" modifications needed to carry an atomic bomb, and these were all assigned to the 509th Bomb Group, which stayed home. As for bombs, the U.S. "stockpile" contained exactly 13, controlled by the Atomic Energy Commission, and President Harry Truman refused to say if he'd ever release them to the military. Even if he had given the order to launch an attack, the 509th would have needed five days to pack up, fly to an AEC depot, load the nukes, and move overseas.

Perhaps the reality of the situation didn't matter to the Soviets. As they demonstrated again and again during the cold war, their pattern was to push until they met a determined response, then back off and wait for the next opportunity. They could easily have prevented an airlift by jamming U.S. radio beacons, but they didn't. And when General Curtis LeMay, to everyone's astonishment, fed and heated Berlin by air, the Russians quietly reopened land routes in the spring of 1949. The blockade succeeded only in burnishing LeMay's reputation, heightening American fear of Russia, and confirming the belief that the B-36 was America's best hope to contain Communism.

In June 1948, Convair delivered the first operational B-36A to SAC's 7th Bomb Group at Carswell Air Force Base, across the runway from its Fort Worth plant. Big as the B-29 Superfort was, it could nearly fit beneath one wing of a B-36. Despite the difference in size, the two airplanes had similar vertical tails, and they had slim fuselages, like cigarettes, round in cross-section, with two pressurized crew cabins separated by two bomb bays and connected by a tunnel.

But the wings were different. The Superfort's were thin, straight, and glider-like, while the B-36's wings were more than seven feet thick at the root, enough for a crewman to crawl in and reach the engines or the landing gear in flight. The wings were tapered, with the leading edges swept back, and the effect of that, combined with the wings' location so far back on the fuselage, made the airplane appear out of balance. Strangest of all, the B-36's six Pratt & Whitney Wasp Major engines were faired into the trailing edges, with the propellers located aft in the pusher configuration. Although it was supposed to reduce the propeller swirl's turbulence over the wing, the pusher design was rarely used on U.S. aircraft. Apparently it worked, though, because the B-36 had very low drag. The main drawback was that air for cooling the engines was ducted from intakes in the leading edge of the wing, and there was never enough of it, especially at high altitude.

The propellers were 19 feet in diameter, and to keep the tips from going supersonic they were geared to turn less than half as fast as the engines. The engines and propellers produced an unforgettable throbbing sound when the B-36 flew overhead. A friend of mine remembers the sound from his boyhood as a "captivating drone. The noise went down to your heels, it was so resonant. It just stopped you in your tracks. You looked up into the sky to try to find this thing, and it was just a tiny cross, it was so high." Others remember that it rattled windows on the ground from 40,000 feet.

The airplane's most eye-catching feature was the Plexiglas canopy that enclosed a flight deck, which, while ample for a crew of four, seemed small on such a whale of a plane. A dome below the nose housed a radar antenna, and two transparent blisters allowed the crew to aim the guns and observe any mechanical breakdowns. The effect was a face like a prairie dog's peering from a burrow, with the flight deck for eyes, the scanning blisters for ears, and the radome for tucked-up paws.

The ailerons, flaps, rudder, and elevators had a combined total surface area greater than both wings of a B-24. The pilot's control input moved a trim tab in the opposite direction, forcing the control surface in the desired direction. Two flight engineers monitored the six 4,360-cubic-inch engines, each with four rows of seven cylinders, a configuration that earned the nickname "corncob." The bombardier, navigator, radioman, and gunners brought the population of the forward cabin to 10.

You could visit the aft cabin by lying supine on a wheeled cart and pulling yourself along an overhead rope through a tunnel 85 feet long and two feet in diameter. The cart also served as a dumbwaiter, sending hot entrees from the galley to the forward cabin. The aft compartment accommodated five men and was equipped with bunks, an electric range, and the world's smallest urinal, which had to be voided to the outside

Stuart Symington (above), flanked by Louis Johnson (left) and General Hoyt Vandenberg (right), was a staunch defender of the B-36. Though the Peacemaker dwarfed the B-29, the bombers were design contemporaries.

at intervals. B-36 veterans like to tell the story of the new captain who came aft to relieve himself but didn't ask for instructions and, as a result, peed on his boots.

Later models had larger crews, up to 22 in reconnaissance versions. And everyone had a job to do—two jobs, in the case of the gunners. It took the ground crew six hours to prepare the bomber for a mission, and the flight crew needed another hour for a preflight check involving 600 steps, beginning with climbing the landing gear and removing the clamps that kept the gear from folding accidentally.

The B-36A couldn't fight—the electrically operated cannon were so trouble-prone they were simply eliminated—much less scramble to retaliate, and it ended up becoming little more than a crew trainer. Twenty-two were delivered, each virtually handmade, and "so flimsily built," says Jim Little, who served on one after it was converted to an RB-36E, "that the upper wing skin would actually pull loose from the wing ribs." Sometimes, Little recalls in the book *RB-36 Days at Rapid City*, "you would meet [the plane] with a crew of 30 or 40 sheet metal men."

The propellers were reversible for braking on landing, but sometimes they reversed in flight or while the airplane was straining to take off—at least once with fatal consequences. The stainless steel firewalls enclosing the engines cracked. The cylinders overheated. Lead in the gasoline fouled the spark plugs at cruising speed. Each airplane had 336 spark plugs, and after a flight lasting a day and a half, a mechanic would have to haul a bucket of replacement plugs to the airplane to service all six engines. The engines leaked oil, and sometimes a flight engineer had to shut one down because it had exhausted its allotment of 150 gallons.

The prototype's single-wheel landing gear could crack most ramps. A four-wheel main gear replaced it.

Then there was the "wet wing." The outboard fuel tanks were formed by the wing panels and sealed at the junctions, and after the wing flexed for a few hundred hours the sealant was apt to fail. Jim Little recalls that one airplane leaked so badly "the ground underneath was just purple [from the dye in the high-octane gasoline]—it was raining fuel under that airplane."

Pilot opinion of the B-36 tended to run to the extremes, but most crew members loved it—"this big, wonderful old bird," Jim Edmundson calls it. As a colonel in the early 1950s, Edmundson commanded a B-36 group at Fairchild Air Force Base near Spokane, Washington. But even he admitted that the airplane could be a chore for its pilot—"like sitting on your front porch and flying your house around."

Of course most of the pilots were young and eager, and the older men had flown worse contraptions during the war. "It was a noisy airplane; it was big," former radioman/gunner Raleigh Watson recalled at a B-36 reunion at the Castle Air Museum in Atwater, California last September, "but it was comfortable, and I think we felt it was a safe airplane, a very well-built airplane." Moxie Shirley, a pilot with more than a thousand hours in the B-36, loved the airplane, declaring that it "kept the Russians off our backs." But he went on to add, "Every crew that ever flew that airplane had stories that would make your hair stand on end."

Ed Griemsmann expressed another view in *Thundering Peacemaker*. "A horrible, lazy beast to fly," he told the book's author. Griemsmann survived a fiery crash in 1956. Most B-36 crashes were fiery because of the magnesium used in its construction. Rather than fly another, he said, he'd join the infantry.

If the B-36A was ineffective, the Strategic Air Command was little better. Its first commander, General George Kenney, didn't believe in the B-36, arguing in 1947 that the bomber was too slow to survive over enemy territory, with engines and an airframe that couldn't withstand an 8,000-mile flight. Kenney urged the Air Force to put its money into bombers that could fly at the speed of sound, even if that meant depending on overseas bases.

Kenney was right, of course. But at the time, his advice seemed disloyal, and he compounded the offense by letting his deputy run SAC while he himself campaigned for the top job in the Air Force. Not long after the first B-36A arrived, Kenney was fired. SAC's new commander was General Curtis LeMay, the pudgy, ferocious, cigar-smoking general famed for his B-29 tactics in the Pacific and for the more recent and successful Berlin airlift.

The D model's four J-47 turbojets boosted top speed somewhat, though crews felt the difference mostly on takeoff. B-36 mechanics suffered in bad weather, but they coped with innovative solutions (below).

"We didn't have one crew, not one crew, in the entire command who could do a professional job," LeMay wrote of the SAC he inherited. He challenged his crews to stage a practice bomb raid on Dayton, Ohio, from 30,000 feet, using photographs taken in 1941—the best they'd have for the Soviet Union. (All SAC had were captured photographs the Germans had taken during the occupation of western Russia. Of the country beyond Moscow, there were no photographs available at all.) After the fiasco that ensued, LeMay whipped the crews into shape. He moved the best people from other groups to make the nuclear-capable 509th combat-ready, then did the same for the next most promising group.

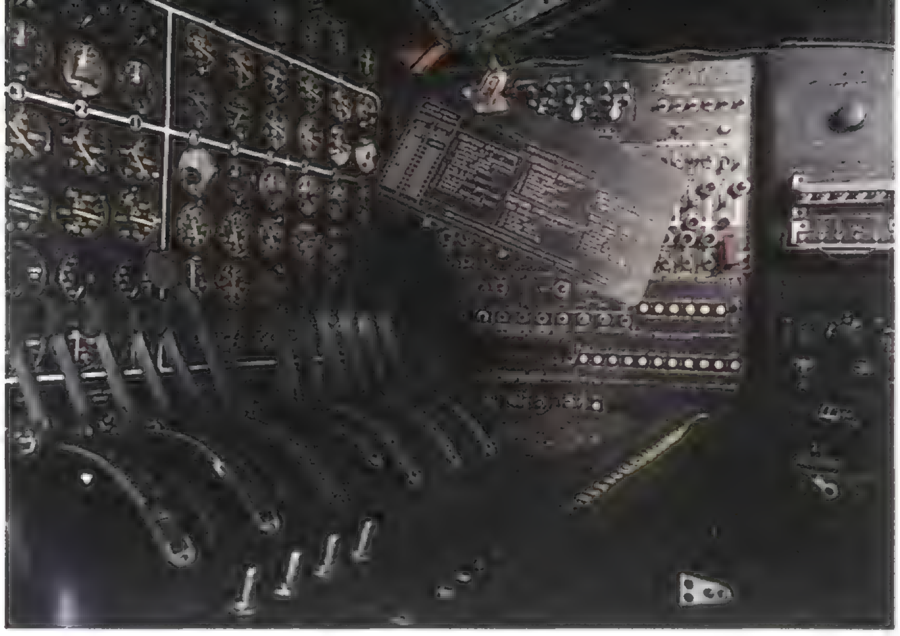
By the fall of 1948 an improved B-36B had arrived, armed with pairs of 20-millimeter guns in the nose and tail, and six turrets that opened out like flowers in a slow-motion film; the gunners aimed from remote blisters. On December 7, the seventh anniversary of the Japanese raid on Pearl Harbor, Lieutenant Colonel John Bartlett took off in a B-36 from Carswell Air Force Base in Texas, flew to Hawaii, dropped a 10,000-pound dummy bomb, and returned without being spotted on the island's radar. LeMay must have bitten through his cigar when he got the news. If he could reach Hawaii from Texas, he could hit the Soviet Union from Maine. And if he could figure out how to operate the B-36 in the cold of Alaska, all of Siberia would fall under its shadow.

The B model also had the "Grand Slam" modifications needed for carrying a hydrogen bomb, which was 30 feet long and weighed 43,000 pounds and had been created in such secrecy that Convair didn't have the dimensions in time for the A models.

The B-36B was the last true reciprocating-engine bomber in the U.S. strategic bomber force. In hindsight, it seems obvious that the mega-bomber should have been jet-powered from the start. But the turbojet had been developed during World War II for fast-climbing, high-flying interceptors, and they gulped fuel at a prodigious rate. Nobody dreamed they could cross an ocean. Two developments changed everything: a new generation of twin-spool turbojets with markedly improved fuel consumption and, more significantly, the advent of inflight refueling. By 1949, Boeing's B-47 Stratojet was entering production, and the B-52 Stratofortress, an intercontinental giant, was making progress on paper.

Even before the uproar started in Congress in the summer of '49, the Air

DAN PATTERSON (4)



The U.S. Air Force Museum took delivery of its B-36J, shown here, on April 30, 1959; the trip there was the last flight ever made by a B-36. Clockwise from upper left: the jet pods, virtually identical to a B-47's; the flight engineers' station, a forest of levers and a mural of gauges; the snug flight deck; the bomb bay, which held the largest and heaviest U.S. thermonuclear weapon, the Mark 17.

Force was apparently worried about the vulnerability of the B-36, and as an interim measure asked Convair to hang a pair of jet pods near the B-36's wingtips. By March, a B-36B had flown with four Allison J35s installed. On the production versions that emerged in July, each pod housed two General Electric J-47-GE-19s modified to run on gasoline—tiny compared to the Wasp Majors, but effectively doubling the airplane's installed horsepower. The jets were employed for takeoff, climbing to extreme altitudes, and dashing across hostile territory. With "six turning and four burning," as the saying went, a B-36 could finally top 400 mph. But fighter jockeys were flirting with the sound barrier in their North American F-86 Sabre jets, and whatever the Americans deployed—nukes, missiles, supersonic jets—the Russians matched, beginning with copies and sometimes ending with improved weapons.

For the benefit of Congress, the Air Force then released what *Aviation Week* described as "sensational new performance figures" on the jet-assisted B-36D: 435-mph top speed, 50,000-foot ceiling, range of up to 12,000 miles. LeMay added his personal pledge: "I believe we can get the B-36 over a target and not have the enemy know it is there until the bombs hit."

Even George Kenney came out of exile from his post as commander of the officer training center, Air University, to praise the airplane. "The B-36 went higher, faster, and farther than anybody thought it would," he said, "and the pilots liked it. It was a lucky freak." However, Kenney guessed that both the U.S. Navy Banshee and the Royal Air Force Vampire could intercept the B-36 in daylight; he recommended that it be used only on night raids.

On September 5, *Aviation Week* reported "Symington and Defense Chiefs Exonerated," as the House Armed Services Committee gave a clean bill of health to Johnson, Symington, the Air Force, and Convair. There wasn't "one iota, not one scintilla, of evidence...that would support charges or insinuations that collusion, fraud, corruption, influence, or favoritism played any part whatsoever in the procurement of the B-36 bomber," the committee concluded. Even Congressman Van Zandt voted for the absolving resolution.

Production rates stepped up after the Soviet threat lent a genuine urgency to the B-36 program.

At 4 a.m. local time on June 25, 1950, North Korean troops stormed across the 38th parallel. In November they were joined by Chinese "volunteers." These developments marked the end of President Truman's defense economy drive. First Germany, then Japan, then Russia, and now events in Korea had succeeded in advancing the cause of the B-36. Suddenly plenty of money was available for mega-bombers, and for super-carriers as well.

The Korean war produced another milestone for SAC: Truman released nine atomic bombs to the military. They probably didn't leave the country, but the B-36 did, flying from Texas to airfields in Britain and Morocco in the spring and fall of 1951. Only six airplanes were involved and their visits were short, but the message couldn't have escaped Moscow's attention. However briefly, the capital and most of the territory of the Soviet Union had come within the combat radius of the B-36.

Altogether, 1951 was a good year for mega-bombers. Margaret Bourke-White rhapsodized over the B-36 in a photo-essay for *Life* magazine, with photographs taken at 41,000 feet, where the sky "was a color such as I've never seen, the darkest blue imaginable, yet luminous like the hottest cobalt, too brilliant for the eyes to bear." She photographed fluffy white contrails streaming from the reciprocating engines, a 55-foot scaffold used to repair the rudder, and (from both ends) the marvelous flying boom that refueled bombers in flight.

An alert reader might have noted some oddities in Bourke-White's essay. The bomber being refueled was a Superfort, not a B-36, none of which was ever equipped for inflight refueling. She rode in a B-47, its raked tail clearly visible in one photograph. And the accompanying map depicted a Soviet Union surrounded by small bombers based in Alaska, Canada, Europe, North Africa, the Middle East, and Japan: the Peacemaker hunkered at home.

But if Superforts were on the Russian border, and if midair refueling allowed them to fly indefinitely, and with the Stratojet coming on line, why bother with the B-36? The jet pods had added so much weight and gobbled so much fuel that the combat radius had dropped first to 3,525 miles, then to 3,110. What was LeMay planning? From Maine, South Dakota, and Washington, the B-36 could barely scratch the edges of the Soviet empire, and even at those bases it faced hard sledding in the winter. At Rapid City, mechanics had to build a repair dock with sliding doors and cutouts for the fuselage so they could work on the engines while the tail stayed out in the snow. There were SAC bases in Alaska and Greenland, but the climate was so forbidding that LeMay never stationed any B-36s there. The Arctic airfields were used as staging points, with the bombers returning to the south 48 after each mission. Another ploy was the shuttle mission, with a takeoff from Fairchild Air Force Base near Spokane, Washington. After bombing Irkutsk, in central Siberia, the bombers would have refueled at Okinawa before returning home.

But to do any real damage, LeMay had to launch it from an overseas base or order a one-way mission. He would have scoffed at this latter-day quarterbacking, of course. "The B-36 was often called an interim bomber," he wrote in his memoir, *Mission With LeMay*. "For my dough, every bomber which ever has been or ever will be is an interim bomber." He had a point: at the time, SAC even considered the B-52 nothing more than a fill-in for the supersonic B-70.

LeMay may have been loyal to his hardware, but there were signs that General Kenney wasn't alone in his initial doubts about the B-36. One scheme would have equipped it with a pilotless drone to fight off enemy interceptors. Then the Air Force experimented with a manned parasite—the XF-85 Goblin—which would ride to war in a bomb bay. Still later, Republic adapted its F-84 to snuggle into the belly of the beast. By 1953 this last concept had changed from one of defending the B-36 to replacing it: The mother plane would linger offshore while the Thunderjet dashed in to take photographs or drop a bomb.

Finally, in 1955, Convair took a different approach, stripping the mega-bomber to the essentials. Just as LeMay had gambled his B-29s in 1945, sending them low and fast over Tokyo armed only with tail guns, SAC got a "featherweight" B-36 with only two guns, a smaller crew, no stove or other luxuries, and, in the bargain, a longer range. Many of the earlier models were modified to the new standard, especially the reconnaissance versions. Indeed, it's possible that LeMay's fondness for the B-36 may have had less to do with its potential as a bomber than its value as a spyplane. SAC ended up with 369 of the jet-recip hybrids, including modified versions, and more than a third were reconnaissance bombers. The RB-36 could carry an atomic bomb, but its principal weapon was a camera the size of a Geo Metro, set in a photo studio that replaced the forward bomb bay. Loaded with a roll of film 18 inches wide and 1,000 feet long, this great camera once photographed a golf course from 40,000 feet, and in the contact print, on display at the Air Force Museum in Dayton, an actual golf ball can be seen. If an RB-36 could see a golf ball from

If you'd like more information about the B-36, browse the Web at www.airspacemag.com/10th/1949.html

eight miles up, it could see tanks, airplanes, missiles, and factories. Surely this was the task that LeMay saw for the Peacemaker: With its enormous wings and extra fuel, who knows how high and how far it could fly? B-36 crews speak of 45-hour missions, presumably with fuel cells instead of nukes in the rear bomb bays; at cruise speed, a "featherweight" could travel almost 9,000 miles in that period. The official ceiling was 41,300 feet, but again, crews say that they routinely flew higher than 50,000 feet, and one man—John McCoy, quoted in *Thundering Peacemaker*—boasted of soaring to 58,000 feet. On missions over China, McCoy said, his RB-36 was chased by MiG fighters that couldn't climb anywhere near it. U.S. fighter pilots of that period also recall B-36s cruising comfortably well above their own maximum altitude. Not until the advent of the "century series" fighters—the F-100 and up—would the B-36 be challenged. Whether the RB-36 ever overflew Russia is anyone's guess, but it was the U.S. altitude and distance champ until the Lockheed U-2 came on line toward the end of the decade.

In the end, the B-36 turned out to be a place holder for the B-52 Stratofortress. Convair attempted to stave off Boeing's intercontinental jet bomber with the YB-60, which premiered as the YB-36G, with eight jets, a five-man crew, completely redesigned swept wings, a speed of 508 mph, and a 2,920-mile combat radius—in short, a knock-off that was inferior in every respect to its competitor. Boeing's bombers had the advantage of having been designed for jet power from the start. The Air Force didn't even bother to supply engines for the second YB-60 prototype.

Though obsolescent, the B-36 still had some momentum. Before descending into retirement, it made its first overseas deployment with a USAF unit in 1955, to Britain and Guam. In the same year, it starred in a Hollywood epic, *Strategic Air Command*—though in Jimmy Stewart's final scene with Frank Lovejoy, who played the LeMay-like general, a model of an early B-52 can be seen on the general's desk. The B-36 remained in the inventory for four more years, while the new Stratofortress was being tweaked to its full potential.

The B-36 was nowhere near as durable as the B-52 would prove to be, but it did the work asked of it. And eventually, the inter-service rivalry that led to the Congressional eruption over the big bomber's strategic mission died down, with the Navy's missile-submarine fleet garnering a permanent place in the strategic "triad" along with bombers and land-based missiles. Perhaps the best thing that can be said about the Peacemaker is that it lived up to its name. The B-36 never went to war, never dropped a bomb in anger, nor (so far as we know) even fired its cannon at an enemy airplane. Created at a time when the atomic bomb redefined strategic air power and the turbojet redefined performance, its career spanned the crossroads that divided two eras.

By the time it posed with a Bell X-5 in 1951, the Air Force's last piston-powered bomber was obsolescent.

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THE WHOLE WORLD'S WATCHING

According to the Beatles, all you needed was love. They didn't mention satellites, ground stations, telephone lines...

by Tom Huntington

Illustrations by David Peters

When the Beatles debuted their song "All You Need Is Love," they did it in a big way. From a London studio packed with flowers and friends, the Fab Four performed the new song for an audience of perhaps as many as 600 million television viewers in 26 nations around the world. The performance was transmitted live via three satellites as part of the most ambitious satellite television extravaganza that had ever been attempted.

It happened on June 25, 1967, not quite ten years after the launch of the first artificial satellite. The two-hour, black-and-white program, titled "Our World," used, in the words of a press release, "the magic of space-age electronics to flash sound and visual images across lands, seas and time zones, fusing 'yesterday,' 'today' and 'tomorrow' into a globe-encircling 'now.'" In addition to the Beatles, highlights included Franco

Zefferelli directing his film version of *Romeo and Juliet* in Italy, Leonard Bernstein and Van Cliburn sparring with pianos in New York, and an astronomer in Australia observing the most distant known object in the universe. Combining the efforts of 14 nations, thousands of technical people, and almost two years of planning, "Our World" pushed the day's communications technology to the limit.

At a time when homeowners can buy their own satellite dishes and receive television transmissions directly from space, satellite communication is often taken for granted. But in the 1960s, satellites were still being hailed as catalysts for the emergence of a global village, a united world tuned to the same uplifting television programs. Shortly after the 1965 launch of the world's first commercial communications satellite, Intelsat 1—better known as Early Bird—the *New York Times*' Jack Gould expressed the optimism of the day, writing: "Early Bird is the forerunner of the era when television will be able to go anywhere in the world and unite mankind in shared experiences so vast as to humble anyone attempting their full contemplation."

Aubrey Singer, a producer with the British Broadcasting Corporation, shared Gould's belief. Singer had cut his teeth on satellites in 1962 with the world's first live transatlantic television broadcasts, made possible by the July launch aboard a NASA Delta vehicle of the American Telephone and Telegraph Company's Telstar 1. In 1965 Singer began thinking about how satellites could link countries the way railroads had pulled together the United States in the previous century. Realizing that a global television program was too big

PHOTOGRAPHS COURTESY NOBLE WILSON ASSOCIATES

for the BBC to tackle alone, Singer turned to the European Broadcasting Union, a cooperative based in Geneva and Brussels that coordinated broadcasting organizations throughout Europe. The EBU agreed to take it on and appointed Singer as the project's head.

In September 1966, following a world tour to determine the project's feasibility, Singer convened a massive meeting in Geneva with people from participating countries. "It was really very difficult to get even a majority of those countries to agree on anything," says William Kobin, then the vice president for programming for National Educational Television (the precursor to today's Corporation for Public Broadcasting), which had joined the program after the three commercial U.S. networks had declined. Sent to Geneva, Kobin arrived jet-lagged and weary, but he left enthusiastic, in no small part due to Singer. "It really was like—it was Aubrey 'Boutros Boutros-Ghali' Singer trying to get this thing to work," he says today. "He was a big, scotch-drinking, cigar-wielding, loud, explosive, funny, emotional power—force, I would say."

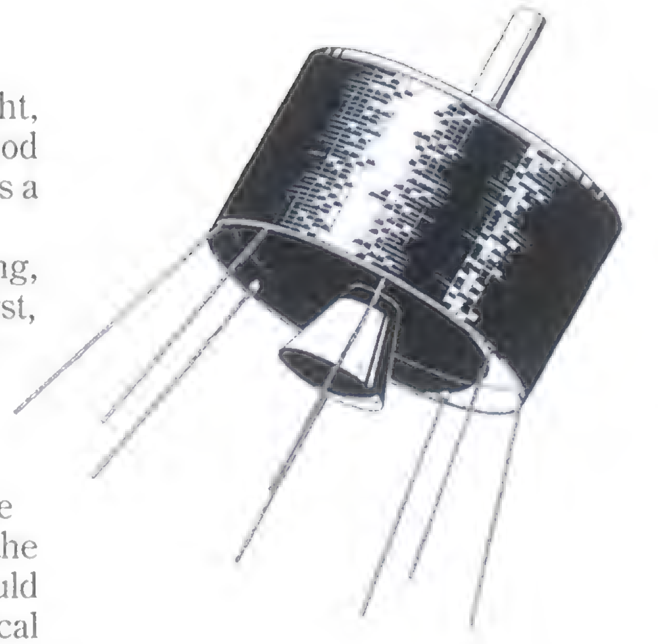
Kobin assigned the project to executive producer Robert Squier, today a high-profile political consultant who will be handling President Clinton's re-election campaign. Squier has fond memories of working for "Our World." "I'd done some pretty good shows by that time of my own and won some awards, but this was a chance to play with the big boys in the big sandbox," he says. Like Kobin, Squier was enormously impressed by Singer's leadership. "Singer was a great character," he says. "There was always a kind of joke among some of us that his real work was running British Intelligence and that he did this as his cover. There was always that aura about Singer, that there was a lot of stuff that you didn't quite get and understand. Very smart, very bright, very funny. Great raconteur, loved good wine. He was a master; he really was a master."

By the end of the Geneva meeting, four principles had been ratified. First, the program would feature no politicians or heads of state. Second, it would be live, without film or recorded material. Third, all participants would have full knowledge of any item to be included. And last, the sole reason for including an item would be program balance, not geographical or political concerns.

Next came the task of transforming the idea of a global telecast into a cohesive program. "We were trying to make it something which was a program in its own right, that was about something and yet had to carry with it—and this was the problem—all the different nations," recalls Antony Jay, the writer recruited for the project. "And so we decided to make population growth—which was one of those preoccupations, like global warming is now—a kind of theme of it. We wanted something to try to capture the maximum audience at the beginning, so we thought: Let's have babies. Typical bit of meretricious television programming, but it gave us a way of getting into it." The program would begin by attending the births of various children in hospital delivery rooms around the world, then examine the world into which they had arrived. It would consider population growth and the means of supporting people on the planet, and also delve into the worlds of culture and science.

The project was divided into several zones. Master Control would be at BBC headquarters in London. Brussels would be headquarters for the EBU, which would include Tunisia, the only African location. Prague was the headquarters for Eastern Europe, and Moscow for the Soviet Union. The western zone would include the United States, Canada, Mexico, Australia, and Japan, with headquarters at the CBS studios in New York City.

Broadcasting "Our World" was not as simple as transmitting a program from London to the rest of the world. New York and London used different television signals. In the U.S., television sets used a picture with 525 lines; in Europe the standard was generally 625 lines. Any visual signal traveling between the United States and Europe had to be converted.



Essentially, the directors in London and New York created mirror-image programs. "They sent us the clean 525, without any 625 contributions, and we sent them the clean 625, without any 525," says Norman Taylor, the head engineer for the BBC. "This meant you had two directors, who had to keep in very close touch because they more or less had to cut in at the same time."

Otherwise, bridging the Atlantic was relatively straightforward. Early Bird, launched by a Delta rocket on April 6, 1965, had introduced regular transatlantic television. It was operated by Intelsat, an international cooperative dominated by a U.S. company, COMSAT. (When a reporter asked COMSAT information chief Matthew Gordon how the satellite would differ from future ones, Gordon joked, "You might call it the early bird." The name stuck.) Early Bird weighed only 85 pounds and could handle a single television transmission or 240 telephone circuits, but not both at the same time. By comparison, today's Intelsat 7 has three television and 90,000 voice circuits.

The Soviet Union would be supplying one of its Molniya satellites to link Vladivostok and Moscow. The program's other comsats were geostationary—they revolved around the equator at the same speed as Earth's rotation—but Molniya 1 satellites were in a very eccentric orbit. Because so much northern Soviet territory lay beyond the reach of geostationary satellites, the Soviets launched satellites with apogees high over the U.S.S.R. As the satellites climbed

"Our World" was the brainchild of BBC producer Aubrey Singer (in glasses, bottom left; producer Noble Wilson is at far left). Coordinated out of BBC headquarters in London, site of the show's set (top), it consisted of live segments from 14 nations, although an elaborate Mexican number was discovered to have been taped.

to and descended from their peak orbital altitude of almost 25,000 miles, they would remain in the line of sight of their ground stations for up to eight hours. Three such satellites in complementary orbits could provide continuous coverage.

The Pacific presented a trickier situation. At the time of the Geneva meeting the two satellites "Our World" would eventually use there—NASA's ATS-1 and Intelsat 2 F2—hadn't even been launched. ATS was launched by an Atlas-Agena D three months later, in December; Intelsat 2 F2 reached its orbital position the following February. Of the two, ATS would play the most important role. "ATS was fundamental to the exercise, actually," recalls "Our World" producer Noble Wilson, a Scotsman who had been with the BBC since 1951. "If we hadn't gotten ATS we would have been in trouble." The 670-pound satellite offered two transponders, devices that receive incoming signals, shift the frequency, and re-transmit them to ground stations. And although each transponder could receive from only one source at a time, it could transmit to several ground stations at once.

The Pacific Theater

"Our World" transmissions from Australia (blue) and Japan (yellow) traveled from NASA's ATS-1 satellite to a ground station in Rosman, North Carolina, which relayed the signals over landlines to the western zone switching center in New York. For European audiences, the signal was then uplinked from a ground station in Andover, Maine, to the Early Bird satellite and back down to a British ground station at Goonhilly Downs in Cornwall (green).

Australia's Toowoomba ground station sent its material via ATS-1's transponder 2 and received the program feed from New York via transponder 1; Japan's Kashima ground station could communicate only with transponder 2. Therefore, when Australia was using that transponder to transmit, Japan would have to take the Australian contributions directly from ATS, or, if juxtaposition of the program segments made that impossible, take the entire program feed from Intelsat 2 F2, a satellite which linked a ground station at Brewster Flats, Washington, with a Japanese ground station in Ibaraki (pink). But Ibaraki could handle only visual signals from the satellite, so the audio signal would have to travel via conventional cables. This meant, in apparent violation of physical laws, that the sound would arrive in Japan before the images. That was because the visual signal would be making a trip of almost 47,000 miles. Project engineers would have to calculate the difference and delay the sound long enough so it would be transmitted in synch with the visual signals. (Japan could also give itself a direct feed of its own signal without routing it to New York and back—a simpler method, perhaps, but one that required the Japanese director to time his switching perfectly to match New York's

Early in the spring of 1967 engineer Eric Griffiths departed to scout the situation. In Japan, he checked out the ground station at Kashima, one of the links with ATS-1, and found it to be a small research station with only five staff members present. "Like any research station it appears to be short of equipment," he wrote in a report to the EBU; "the only beautifully engineered equipment on the station is the antenna itself." Griffiths discovered that Kashima could communicate only with the number-two transponder. A new receiver was available, but the station director told Griffiths that it was unlikely it could be installed by the broadcast date, and he appeared extremely hesitant to make any changes in operations. Griffiths decided not to press the issue.

and left Japan with a gap during the short time it took to switch from "transmit" to "receive" with ATS.)

When neither Australia nor Japan was transmitting its own material, the Rosman station transmitted "Our World" program feed to those countries (red) by uplinking to transponder 1, which would then relay the signal to Toowoomba and, at the same time, to another ground station in California's Mojave Desert. Mojave would then loop the signal back to transponder 2 for downlink to Japan.

At Australia's Toowoomba station, Griffiths found a large staff—30 on each shift—cramped together in trailers. Like Kashima's, Toowoomba's transmitter was tuned to send to transponder 2. Although it could receive from both transponders, it had only a single filter for processing visual signals and therefore could not receive television transmission from both simultaneously. When Griffiths asked if Toowoomba's equipment could be retuned to transmit to transponder 1, he was told it would be "very sticky." In the end, such ground station limitations required elaborate planning to make use of the two satellites (see "The Pacific Theater," left).

Add to that the need for telephone circuits to all the participating countries and all the field sites, lines from London to guide and coordinate the entire production, plus phone lines for the translation the commentators in each country would need, and you had a task that was unbelievably complicated.

Surprisingly, satellite failures were low on the list of worries. More threatening was the loss of an undersea cable, which would have forced the telephone companies to shanghai the satellites for telephone and cable traffic. In those days the satellites didn't have dedicated television channels: To make space for the television signals, all telephone transmission had to be reverted to cable. "And one of the big worries was defense circuits between the Pentagon and military defense," Norman Taylor recalls. "If the cable went, if a trawler broke the cable or something like that, they would immediately take the satellite away from us to restore the defense circuits." In fact, two years previously Early Bird had justified its nickname by going into service ahead of schedule after an Atlantic cable had been cut.

As if the technical details weren't difficult enough, on the fifth day of June the political situation exploded with the outbreak of the Six-Day War in the Middle East. To protest the Western response, the Soviet Union pulled out of the program only four days before broadcast, taking the other Eastern Bloc countries that were to participate—Poland, Czechoslovakia, Hungary, and East Germany—along with it.

Says Squier, "It made an irony of our title—'Our World.' Their world dropped out."

The producer for the Soviet zone was Yuri Fokin. The first commentator on Soviet television, Fokin had met Aubrey Singer through joint projects with the BBC. For Fokin, the Soviet decision to pull out was a great disappointment. His control room in Moscow had been finished, and preparations for his segments, which were to include cosmonaut Yuri Gagarin visiting a children's camp at Odessa as well as a live shot of Earth from a Soviet weather satellite, were well under way. "To a certain extent it was my personal tragedy because my colleagues with whom I was working with in the Soviet television network, they were doing everything to show what we can do," says Fokin today.

By broadcast time Fokin was devastated. "I was sitting in our cosmic studio in Soviet television network, watching this broadcast, crying," he says. As he recalled the incidents from 1967 on the telephone from his home in Moscow, Fokin was hoping to watch the imminent launch of the space shuttle *Atlantis* on its mission to dock with the Russian space station Mir. He hoped to see portions of the mission live over CNN. "At that time, 20, 25 years ago, we were just thinking about the possibility of making such a worldwide link," he says. "That was a dream. But now that dream is coming true."

When Singer learned of the Soviet Union's withdrawal, his initial reaction was to cancel the program. A long talk with project writer Antony Jay changed his mind. "It was Tony's steadfastness that kept it on the rails; I was rather panic stricken," Singer recalls.

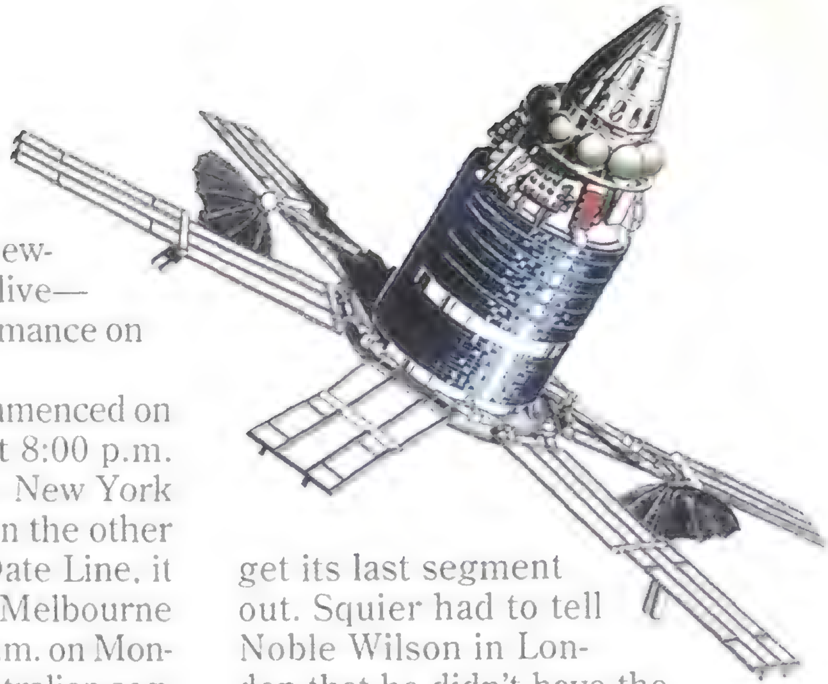
"As far as the audience was concerned, we went around the world, just without a few stops," Jay says. "They got an express instead of a stopping train."

The pullout necessitated immediate script revisions, which had to be prompt-

ly sent out to all the participants. "The only way of doing this was by telex," Noble Wilson remembers. "And the telexes that went out to each country were 11 feet long."

A dress rehearsal of "Our World" was conducted the day before broadcast. It went surprisingly smoothly, except for an incident involving the Mexican contribution, a remarkably complex production that included singers, dancers, men on horseback, and a flock of white doves that took off right on cue from the main square in Mexico City. "We got through the first rehearsal and it was unbelievably good," recalls Squier. "Their rehearsal was the best rehearsal we'd ever seen. We go through the next rehearsal and it's flawless." What struck everyone watching the rehearsal was how the birds managed to take off with perfect timing—each time. "I called Aubrey or Noble," says Squier, "and I said, 'I don't want to seem paranoid, but the pigeon winked at the same time.' And they said, 'Yeah, we noticed.' "

In violation of one of the four basic ground rules established in Geneva, the Mexicans had pre-recorded their segment and attempted to pass it off as live. Singer immediately got on the line to Mexico. "I remember [Mexican producer] Roberto Kenny saying, 'Aubrey, what does it matter if it's live or recorded? It doesn't matter; it's all there,' " Singer says. After what Squier recalls as a "heated exchange," a compromise was struck. The Mexican technical crew had already dispersed, and getting them back together by showtime was impossible. Instead, the cast reassembled for the broadcast, and the viewing audience saw them—live—watching their taped performance on monitors.



The actual broadcast commenced on Sunday, June 25, 1967, at 8:00 p.m. Greenwich Mean Time. In New York it was 3:00 p.m. In Japan, on the other side of the International Date Line, it was 4:00 a.m. Monday. In Melbourne the program began at 5:00 a.m. on Monday, just in time for the Australian segment to feature the morning's first streetcar hitting the streets. And after all the difficulty of pulling the program together, it ran flawlessly. The only failure came just before air time, when the program title vanished off the machine carrying it, only to return moments later. Says Wilson: "It was the nearest I've ever come to heart failure."

Perhaps it was a good omen that in the opening sequence the Mexican baby arrived with perfect timing—on air. Over the next two hours viewers visited a farm in Wisconsin, a shrimp farm in Japan, the Kennedy Space Center in Florida, and the Parkes radio telescope in Australia.

And, of course, there were the Beatles. On June 1 the band had released its groundbreaking album, *Sgt Pepper's Lonely Hearts Club Band*, turning popular music on its ear and kicking off the so-called "Summer of Love." In the entertainment world, the Beatles were the biggest thing imaginable. "That took 90 phone calls, to get the bloody Beatles to participate," says Singer. "They were just so obdurate. Is that the word I want? They didn't feel it was important to them. Thank God we got 'em, because we needed something like that to lift the whole thing."

"In rehearsal it wasn't great," says Squier. "They just kind of dogged it. And then they came on the air and just blew out the circuits. It was a very exciting moment. It was a great anchor to that program. The Beatles doing an original composition really gave stature to the program."

The closest "Our World" came to on-air failure was when a sudden downpour hit the ground station at Kashima. The personnel there were afraid to shut down equipment to reverse the feed to transponder 2, leaving Australia with no way to get its last segment out. Squier had to tell Noble Wilson in London that he didn't have the signal, and they launched into a routine to hurry the next sequence in the script up to the plate. They were almost at the close of the show when Squier realized the picture was going to come through after all. "I said to Noble, 'Trust me. I've got it.' And that was absolutely alien to all the protocols—not possible, not going to do it—and he said, 'Are you sure?' And I said, 'Yeah.' And he said, 'Okay, you've got it.' And he gave me the shot. The thing came up once, went down once, came up once—*three-two-one, hit it*—and it was literally an electronic miracle."

"Our World" was over. Reviews were generally positive, using adjectives like "brilliant," "impressive," and "remarkable." "What gave it special appeal, of course, was the fact that it was live," said the *New York Daily News*. "It was, indeed, a fantastic display of just how small this globe is," said the *Los Angeles Herald Examiner*. The *New York Times* saw it as "a compelling reaffirmation of the potential of the home screen to help unify the peoples of the world." The *Times of London*, however, was not bowled over. "I hope next time there is still more attention to content and much less pious wonderment at the thing happening at all," its reviewer wrote.

There was a next time. Three years later, in 1970, the "Our World" team reassembled to do a similar program, "Children of the World," with Danny Kaye as host. The format was similar, but some of the excitement was gone. With "Our World," Squier says, a lot of people were hesitant to get involved because they thought it couldn't be done. "By the time we got around to 'Children of the World'...it was the other way around: If you didn't bring it off you were a fool, because these things were being done all the time."

To learn more about "Our World," browse the Web at http://www.airspacemag.com/10th/1967.html

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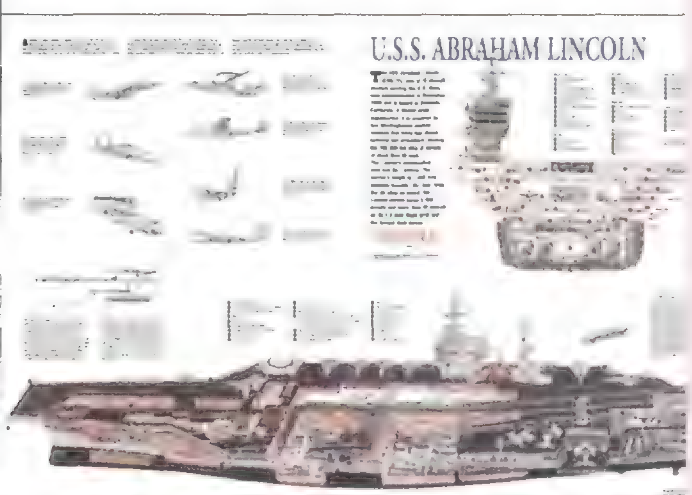

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THE FRENCH SUCCESSION

The Americans won the race to the moon, but France is winning the contest for launch customers.

by William Triplett

Portraits by Richard Kalvar/ Magnum

In 1972 some of the most riveting stories on television appeared during the summer Olympic games held in Munich. There was Frank Shorter, an American who won the marathon by running alone and unchallenged for the last half of the race, American swimmer Mark Spitz, who won an unprecedented seven gold medals, and most memorable of all, tiny Soviet gymnast Olga Korbut, who whirled her way to fame on the uneven bars and softened cold war tensions with her smile. But joyous events are sometimes marred by grief; in the midst of the victories in Munich, a terrorist attack left 11 Israeli athletes dead.

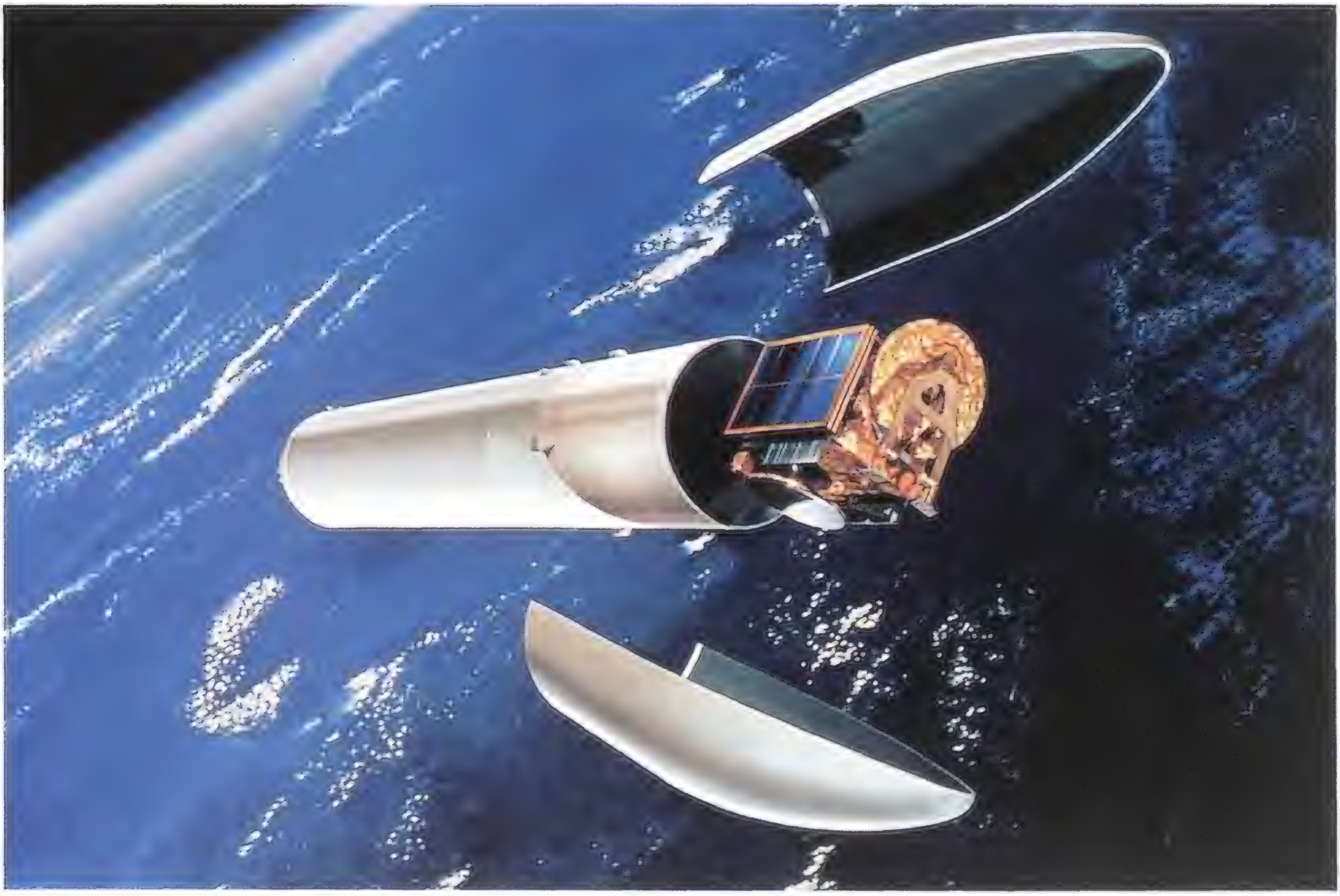
The whole world tuned in daily to watch these unfolding dramas on their television sets, and if the result was a global experience of human triumph and tragedy, it was brought about by pure technology—in this case, signals beamed down from communications satellites. Most of the satellites were owned by American companies, and they eagerly sold their services to foreign customers. But Europeans, particularly the French and Germans, had tired of depending on U.S. technology. And so, to freely watch their own athletes compete in Munich, France and West Germany had pooled their efforts and built their own communications satellite: Symphonie. From the eastern shores of the Atlantic to the Adriatic, from the North Sea to the Mediterranean, there was excited anticipation about enjoying the fruits of home-grown technology.


CNES/ESA/ARIANESPACE

There was, however, the matter of getting Symphonie into orbit. Several European countries had spent eight years developing a heavy launcher named Europa, but the French and Germans dared not use it; a string of humiliating Europa failures had left them too doubtful of the launcher. They turned instead to the U.S. space agency NASA, still riding high after having sent the first men to the moon just three years earlier.

NASA was happy to oblige—on one condition: Symphonie could not be used commercially. That, of course, was its intended purpose. NASA claimed to be protecting the rights of commercial satellites it had already launched, but all of Europe saw the episode as an egregious attempt by the world's leader in space to maintain control of the heavens.

Europe suddenly realized it needed more than just its own satellite. "Symphonie made it clear to everyone that Europe needed its own launcher," says Frédéric d'Allest, then a young engineer working for the Centre National d'Etudes Spatiales (CNES, France's equivalent of NASA). "We were not about to remain dependent on anyone for launch



The long-awaited launch of Ariane 1 on December 24, 1979 (left), marked the beginning of French dominance in the commercial launch market. Seventeen years later, the French hope to stay ahead of the competition with the powerful Ariane 5, which can propel 15,000 pounds to a geostationary transfer orbit (above). Its first launch is scheduled for May.

services. The issue was clearly sovereignty." Symphonie would eventually be launched by NASA aboard a Thor Delta in 1974, but for the French, *l'affaire Symphonie* triggered a sustained fury that would motivate them to emerge from the shadow of the Americans by creating the most successful commercial launch service in space history.

Three months after the games in Munich, European space officials met in Brussels to discuss their renewed commitment to build a heavy launcher in the still-rippling wake of Europa's demise. In theory, Europa had seemed a sensible approach: The British were to develop the first stage (based on the successful first stage of an intercontinental ballistic missile they had developed in the 1950s but had abandoned due to lack of funds), the French were to develop the second, and the Germans were to put together the third stage. The reality turned out to be a kluge. "They thought they could all just meet at the launch site, put it together, and launch it," says Allan McCaskill, an American engineer recently retired from the commercial space industry. "That doesn't work."

Guy Dubau, a French engineer who worked on Europa's launch operations, says the rocket was "a mosaic of egoism." Like three heads wanting to go in three directions, the tripartite project had no centralized authority or even a prime contractor. "The one person in charge was a diplomat," recalls Raymond Orye, a Belgian engineer and former artillery man involved with the project. "You can't be making compromises!" In addition, Europa's budget was underfunded and its mission poorly defined.

Then there were cultural clashes. "Everyone had a different mentality," says Mathias Trotin, a former launch operations engineer. "We French, for example, are less organized than, say, the Danes, but we're more inventive. But if the Danes say they're going to do something a certain way, that is how they will do it. The French change their minds every day." The upshot was that Europa's three stages essentially became three separate systems that could never be successfully integrated. Europa-1 failed in six straight test flights; Europa-2 was tested only once, the third-stage failure being enough to make the partners talk to the Americans about launching Symphonie.

What kind of rocket would they now try to build, and who would design it? At the Brussels meeting, the French said they had been working on a new launcher design of their own and just happened to have the plans with them. These were for a rocket named E-III-S, essentially France's version of a third-generation Europa vehicle. The name, however, caused an immediate uproar. "Someone said: 'You can't call the new program by an old name that was full of bad luck!' " remembers Trotin. But information packets bearing the E-III-S logo had already been printed, so that night, before handing the

packets out to the other partners, the French delegation used correction fluid to change the program name to L-III-S, which would stand for, roughly, Third Generation Launcher.

Frédéric d'Allest (left) and Roger Vignelles (below), who both worked on the failed Europa program, felt that France should build its own launcher. "We were not about to remain dependent on anyone for launch services," says d'Allest. "The issue was clearly sovereignty."

The enthusiasm of the other partners fell somewhere between *comme çi* and *comme ça*. The proposed technology seemed reliable, yes, but nothing about L-III-S was new, daring, or exciting—qualities that seemed necessary now that NASA was touting its development of a winged, reusable vehicle that would, among other things, put satellites into orbit at less than the cost of using an expendable launch vehicle. France tried to persuade the partners to put their faith in French aerospace experience. "We had made multi-purpose aircraft and found they are very expensive and don't work very well at any one thing," says Guy Dubau; he, d'Allest, and several other French engineers believed that NASA's space shuttle would not be able to launch as often or as cheaply as was being advertised, and that the L-III-S could therefore compete. "It was a gamble," Dubau admits now, "but we thought we could do it."

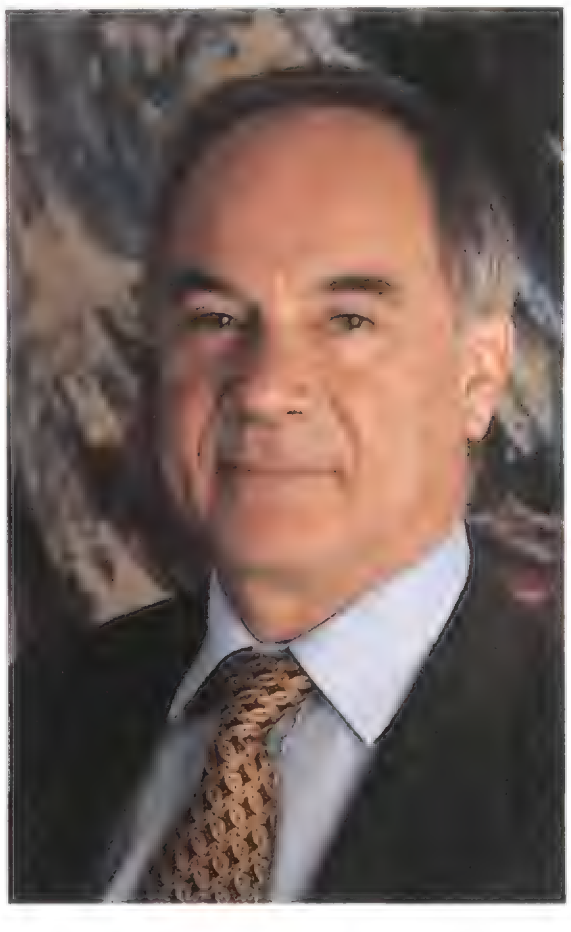
As a show of their own faith, France offered to put up the lion's share of the development money—62.5 percent. The others liked that but decided to push the French for an even larger financial commitment. Cost overruns up to 20 percent of the original price tag would be divided among all partners as usual; above that, France would have to eat everything—not exactly the kind of gastronomic experience the French normally enjoy. But they accepted the terms. "We almost had no other choice," says Roger Vignelles, then a young CNES engineer. The fiscal crises that Britain had suffered in the 1960s continued to cast a pall over the early 1970s, and, for political reasons, Germany still had to be very careful about how ardently it renewed its pursuit of rocketry.

In July 1973, all 10 partners—Belgium, France, Germany, Italy, the Netherlands, Denmark, Spain, Sweden, Switzerland, and the United Kingdom—officially committed to the project. But because it would bear most of the financial risk, France, via CNES, took control. Which surprised no one. "When the French say 'Europe,' they usually mean France," says a non-French aerospace engineer with a wry smile.

Among the first things CNES did was re-christen the project, this time Ariane, French for Ariadne, who, according to Greek mythology, gave a spool of thread to Theseus so that he could find his way out of a labyrinth. The overt parallel—that the Ariane program was going to lead Europe out of a maze of failures—hid a more subtle one, no doubt unintended. In trying to make their way in the space business, the French were depending on a rocket design that, comparatively speaking, was not much more sophisticated than a spool of thread. "You have to be more than confident to do something like this," says Dubau. "You also have to be a little crazy."

You also have to be French, one might say. Since the end of World War II, France, alone among her European neighbors, had steadily pursued some kind of space program, largely because France alone had Charles de Gaulle as a leader. Having seen his people suffer greatly during the war and having caught a glimpse in the German V-2 rockets of what wars of the future would be like, de Gaulle and his government promoted and financed missile R&D with the hope that France would never again be dependent on another nation to defend it. The U.S. and the Soviet Union would without question have the biggest roles in the new era, but de Gaulle felt sure there was room for another player. Moreover, the devastation of postwar France did not fit the image de Gaulle had of his country becoming a world leader again, and it is no coincidence that he pushed hardest for space development around the time France's colonial empire was crumbling.

France had its own aerospace scientists and engineers in the late 1940s and early 1950s, but the primary brains of de Gaulle's space program came from Germany—the V-2 factory at Peenemünde to be exact—where the French managed to grab about a half-dozen Nazi rocket scientists. Initially de Gaulle wanted them to concentrate almost exclusively on nuclear missile technology. But in October 1957 the Soviet Union launched Sputnik, and four months later the United States launched Explorer 1. De Gaulle then decided that conquering space would serve scientific and communications interests far beyond those of national defense. In 1961 he created CNES and charged it with developing civil space applications.



The first task CNES faced was to come up with a launch vehicle. Fortunately, military R&D had years before laid the groundwork for a three-stage launcher. CNES took this foundation and built a rocket it named

Diamant (Diamond). "We all learned our jobs on Diamant," says Roger Vignelles. The project was ostensibly undertaken to demonstrate that the French could put a small payload into orbit, but mainly, says Vignelles, "it was to gain the know-how of mastering the launcher." In November 1965, four years after startup, a Diamant rocket lifted off from a pad in Algeria carrying Asterix, a 92-pound satellite named after France's hugely popular comic strip character.

The Diamant success emboldened the French, who had joined their neighbors in building Europa in 1962. Ironically, the eventual Europa failure only bolstered French confidence. CNES engineers believed that the problems that brought down Europa were managerial, not technological. Had the program been run under one authority, the French reasoned, Europa probably would have succeeded. So for Ariane, CNES would handle the selection of all contractors. For systems integrator, the agency chose Aérospatiale, which had served the same role for the French nuclear missile program. "All contracts were done on a firm, fixed price with no cost overruns allowed," says CNES' Roland Deschamps.

The imperative of staying well within the envelope—financial, scheduling, and otherwise—extended to the most important part of the Ariane project, the rocket's design. Ariane's managers wanted to rely on proven technology as much as possible. While most of Europa 1 and 2's technology was shunned, CNES did use some of their electrical systems. But mostly CNES drew from Franco-German handiwork. The first stage was to be powered by four Viking engines, which were derived from an experimental engine that a former member of the V-2 team had designed for France in the 1960s. Like the Diamant-B's engines, the Viking would be liquid-fueled.

Unlike the Diamant, however, the Viking would employ turbopumps to feed the fuel. The objective was to produce more thrust. On the Diamant, the fuel was injected into the combustion chamber by pressurized gas in the fuel tanks. Higher gas pressure provided more thrust but also required that the tanks be thicker, thereby increasing their weight. With a turbopump to inject fuel, the fuel pressure could be jacked up with only a marginal jump in the Viking's weight. The result? "An increase in thrust and power by a coefficient of ten," says Ariane engineer Jean-Michel Desobeau.

"WHEN THE FRENCH SAY 'EUROPE,' THEY USUALLY MEAN FRANCE," SAYS A NON-FRENCH AEROSPACE ENGINEER WITH A WRY SMILE.

Ariane's second stage would be similarly powered (using only one Viking engine), and the combined thrust of the first and second stages would place the payload and the third stage into low Earth orbit. The third stage, then, would require some innovation, for it had to propel the satellite into a geostationary transfer orbit (GTO). (Once there, the satellite's own thrusters would propel it to its final destination: geostationary orbit, a path some 22,000 miles above the equator that is favorable to the requirements of communications satellites.)

For Ariane's third stage, CNES engineers decided on cryogenically fueled engines, even though they had relatively little experience working with such technology, which involves the delicate manipulation of supercold liquid oxygen and liquid hydrogen. The extreme temperatures would require robust hardware: Liquid hydrogen starts off at a frigid -423°F but ends up generating gases in excess of 3,141°F. "The thermal constraints on piping, valves, and pumps are crazy," says Desobeau. But the engineers decided that the risk of working with an unknown was worth the payoff: a quantum leap in thrust and power, which would be necessary to boost the payload to GTO.

Still, the operative words were "minimize risk" with the hope of maximizing success down the road. After all, the pressure was on. Another failure would mean more than the end of an independent European launch vehicle—it would also be a severe blow to France's credibility not just in space but in any kind of sophisticated technology. Furthermore, not only money was tight; so was time. CNES had promised the other partners to have the launcher flying by 1979. With failure or even setbacks not really an option, a simple, conservative approach was essential.

This, of course, was the approach that had so underwhelmed CNES' partners at their initial meeting in 1972, and had also prompted cutting comments from NASA officials, who asked the Europeans why they were building such an "old" rocket when the futuristic shut-

Arianespace launches from the lush, humid town of Kourou, French Guiana. Its proximity to the equator confers the full benefit of Earth's spin and thus provides a boost to Ariane launchers lifting payloads into an equatorial orbit, which favorably positions them for their final geostationary destination.

Guy Dubau (below, right), an operations engineer for the launch of Ariane 1, remained calm even when an explosion in a pressure gauge threatened ruin.

tle would do everything from launching satellites to supporting a space station. That sort of ribbing might have been expected from the Americans, but it was unpleasantly surprising to hear the French media do the same. "We were criticized by our journalists for doing something with no imagination when the Americans could go to the moon," says Vignelles. Only one magazine—*L'Humanité*, a communist publication—supported the Ariane program.

The gibes and criticisms revealed two different philosophies about space. While the French certainly were after international prestige, they were shrewd enough to realize they could not compete with the resources and know-how of the United States. Their goal was simply propelling a payload to a geostationary transfer orbit. For the United States, however, space was still an arena for dramatic displays of power and capability—characteristics important in waging a cold war. But France had no interest in sending messages to the Soviets. "The important thing wasn't getting to orbit with new or old technology," says Vignelles. "The thing was getting to orbit safely and at the lowest cost."

CNES simply forged on. Development of the Viking engines progressed well through ground tests, but there were minor troubles with the third stage's tricky cryogenics. "The common bulkhead cracked and separated when we filled the thing with the cryogenic [fuel] for the first time," recalls Jaeger.

Still, as d'Allest remembers it, the biggest challenges were not technological but cultural. "It took two years just to get a common technical language," he says. While he acknowledges the value of having technicians with diverse backgrounds and of different nationalities, he says that initially, the lack of clear design criteria, even a definition of what was acceptable, threatened to unravel Ariane in a repeat of Europa. Fortunately, Aérospatiale, the systems integrator, took control and set all terms.

The next hitch came in 1977. CNES would have a rocket ready to test fly in two years as promised, but soon afterward it might have no more rockets. During the conference in which the European partners had officially adopted the Ariane program, they had agreed to build four rockets for con-

For more information about Arianespace, browse the Web at www.airspacemag.com/10th/1979.html

ducting test flights. No one was willing to commit funds for additional launchers until clients were lined up. But clients were not about to get in line without a commitment to build more launchers, creating a Catch-22 situation. To prevent the Ariane program from ending after its fourth test flight, d'Allest began to think of radically altering the way in which the launcher was to be marketed.

Originally the idea was for the European Space Agency (ESA) to offer launch services more or less as NASA did—for both government and commercial customers. ESA would pay particular attention to the latter so that the program could pay for itself. "But no one thought of Ariane as a total commercial venture back then," says d'Allest. "The motive was still political: to have our own launch capability."

But potential clients would have little incentive to sign up with just another government agency, especially one refusing to commit to building future launchers. "That's when we started talking of creating a commercial company," says d'Allest. It would operate much like any other retailer, complete with fixed prices, scheduled service, insurance, and financing—lures that would, with luck, get customers to sign on. With business plan in hand, d'Allest and Raymond Orye were dispatched to the United States to woo customers away from NASA.

It wasn't hard. One of the first persons they met was Fred Ormsby, then a COMSAT engineer on contract to Intelsat, an international consortium that owns and operates dozens of communications satellites. "The shuttle people were impossible," recalls Ormsby. "They just wanted to fly the shuttle; they didn't care what payload was on it, and so they put all sorts of impossible demands on the customer." Such as asking the client to integrate his spacecraft with shuttle payload bay specifications—"a rather painful process," remembers Allan McCaskill, who is now retired from Intelsat. Says C.J. Waylan, then president of GTE Spacenet: "The shuttle office was all driven by governmental rather than commercial concepts. It was not a negotiation. It was a take-it-or-leave-it proposition. You never felt like a customer."

Ormsby and McCaskill wanted to go back to the extremely user-friendly Atlas Centaur rockets Intelsat had flown on before, but NASA said it was phasing out expendable launch vehicles in favor of the shuttle. Right about then Orye and d'Allest showed up. "As an international organization, Intelsat was always interested in broadening its sources of launch supplies, if you will," says McCaskill. While not completely ruling out the shuttle, McCaskill and Ormsby went to Paris to take a closer look at things and liked what they saw. "I was not particularly impressed by any of their hardware," says McCaskill. "It was all proven technology, all adequate. But that was a plus, because if you want high reliability it's better to keep things simple." (Indeed, the shuttle's complexity was proving to be one of its more off-putting characteristics when it came time to integrate the payload.)

After a series of meetings and a trip to South America to inspect the Ariane launch facilities in Kourou, French Guiana, Intelsat signed on in January 1979 for one launch. GTE also signed on, Waylan having found dealing with a commercial supplier "refreshing." Both customers were assuming, of course, that the first test flight of the new vehicle later that year would be a success.

"THE SHUTTLE PEOPLE WERE IMPOSSIBLE. THEY PUT ALL SORTS OF IMPOSSIBLE DEMANDS ON THE CUSTOMER."

With the development of Ariane 1 coming along well and with clients in line—in short, with almost everything on the verge of finally running smoothly—some of the CNES engineers disagreed about how to conduct the much anticipated first launch. Some wanted to go the traditional route of incremental testing, mating the first stage with mockups of the second and third stages, then the first and second stage with a mock-up of the third, and finally the entire rocket. "I said no," says d'Allest. "I did not want this approach because it would have meant more time and money." Vignelles agreed, explaining that incremental testing would not be necessary since almost all of the engine technology had already been proven one way or another. The main concern of the traditionalists was the rocket's cryogenic third stage, but d'Allest and Vignelles, certain that all the technology would work, adamantly opposed any flights with mockups. They fought for the chance to test the whole of Ariane 1 in one shot. And they got it.


LMLV 1
ROKOT
PSLV
LONG MARCH 4
ARIANE 40
DELTA
ATLAS II
PEGASUS
M-3 SII
KOSMOS
LONG MARCH 2
MOLNIYA
SHAVIT
TITAN II SLV
TSYKLON
LONG MARCH 3
START
TAURUS

ROCKET WORLD

Launch vehicles currently in production that have placed a satellite in orbit by 1996

KEY TO SPECIFICATIONS

a. primary mission
b. performance (LEO refers to low earth orbit, altitudes between approximately 450 and 1,000 miles. GTO refers to geostationary transfer orbit, an elliptical orbit with an apogee at 22,000 miles and a perigee at about 450 miles. GEO refers to geosynchronous orbit, a circular orbit with an altitude of 22,000 miles. A launch vehicle's performance will vary with orbital shape and launch site).
c. 1st launch
d. launch record (successes/attempts) as of 12/31/95
e. stages
f. gross liftoff weight (GLOW)
g. manufacturer

CHINA

The participation of China's Long March launch vehicles in the world market has been handicapped by political issues and by charges of unfair pricing by U.S. launch companies and the European Arianespace. (Western launch organizations charge between $60 and $100 million to place a typical communications satellite in GTO; comparable Long March 2E launches have cost between 5 and 40 percent less.) Recently the U.S. and Chinese governments negotiated a cap on the number of international commercial satellites that could be launched by Long March boosters: 20, between 1995 and 2001. They also agreed to a lower limit on the charge for Chinese launches. The U.S. policy is an effort to protect this country's commercial launch industry without penalizing its satellite industry, which wants China's business. The country is the world's largest market for communications satellites. China's first commercial payload, Asiasat 1, launched by a Long March 3 in 1990, was built by a U.S. company, Hughes Space and Communications.

The original Long March launchers were developed from the Chinese intermediate-range and intercontinental ballistic missiles. China Aerospace Corporation is developing a more powerful Long March combining components of the CZ-2E, the nation's current mainstay, with a cryogenic upper stage. The combination is expected to give China a booster in the same weight class as the heaviest Ariane 4; however, the booster failed on its first attempt in February.

1. Long March 2 (CZ-2C)
a. recoverable reconnaissance, remote sensing, and scientific satellites
b. 7,000 lbs. to LEO, 2,200 lbs. to GTO
c. 1975
d. 35/37 (for family, since 1970)
e. two hypergolic stages; optional solid upper stage
f. 210 tons
g. Shanghai Bureau of Astronautics

2. Long March 4
a. scientific and meteorological satellites
b. 8,800 lbs. to LEO
c. 1988
d. 35/37 (for family, since 1970)
e. three hypergolic stages
f. 274 tons
g. Shanghai Bureau of Astronautics

3. Long March 3
a. communications satellites
b. 11,000 lbs. to LEO, 3,100 lbs. to GTO
c. 1984
d. 35/37 (for family, since 1970)
e. two hypergolic stages and one cryogenic stage
f. 224 tons
g. Shanghai Bureau of Astronautics

4. Long March 3A
a. multiple payloads; communications satellites
b. 18,700 lbs. to LEO, 5,100 lbs. to GTO
c. 1994
d. 35/37 (for family, since 1970)
e. two hypergolic stages and one cryogenic stage
f. 264 tons
g. Shanghai Bureau of Astronautics

5. Long March 2E
a. communications satellites
b. 19,400 lbs. to LEO, 6,900 lbs. to GTO
c. 1992
d. 35/37 (for family, since 1970)
e. two hypergolic stages and four hypergolic strap-ons
f. 508 tons
g. Shanghai Bureau of Astronautics

EUROPE

With its family of Ariane 4 launch vehicles, the European launch consortium Arianespace has gained more than 50 percent of the world commercial launch market. Arianespace launched 13 satellites on 11 flights in 1995 and plans 12 launches in 1996, when it will also introduce the Ariane 5. A heavy-lift booster, Ariane 5 is intended to maintain Arianespace's dominance over the commercial launch market with the eventual capability to place two heavy communications satellites in GTO with one launch.

Ariane 1, first launched in 1979, inherited technology from the Europa project, which was begun in 1964 and canceled in 1973 after four attempts at orbit all failed, and from France's Diamant, which had 10 successful launches of 12 between 1965 and 1975.

6. Ariane 40
a. communications and remote sensing satellites
b. 10,200 lbs. to LEO, 4,700 lbs. to GTO
c. 1990
d. 74/81 (for family, since 1979)
e. two hypergolic stages and one cryogenic stage
f. 267 tons
g. Arianespace

7. Ariane 42P
a. communications satellites
b. 13,300 lbs. to LEO, 6,420 lbs. to GTO
c. 1990
d. 74/81 (for family, since 1979)
e. two hypergolic stages, one cryogenic stage, and two solid strap-ons
f. 352 tons
g. Arianespace

8. Ariane 44P
a. communications satellites
b. 14,400 lbs. to LEO, 7,640 lbs. to GTO
c. 1991
d. 74/81 (for family, since 1979)
e. two hypergolic stages, one cryogenic stage, and four solid strap-ons
f. 391 tons
g. Arianespace

9. Ariane 42L
a. communications satellites
b. 7,840 lbs. to GTO
c. 1993
d. 74/81 (for family, since 1979)
e. two hypergolic stages, one cryogenic stage, and two hypergolic strap-ons
f. 399 tons
g. Arianespace

10. Ariane 44LP
a. communications satellites
b. 9,310 lbs. to GTO
c. 1988
d. 74/81 (for family, since 1979)
e. two hypergolic stages, one cryogenic stage, two solid-strap-ons and two hypergolic strap-ons
f. 460 tons
g. Arianespace

11. Ariane 44L
a. communications satellites
b. 10,400 lbs. to GTO
c. 1989
d. 74/81 (for family, since 1979)
e. two hypergolic stages, one cryogenic stage, and four hypergolic strap-ons
f. 517 tons
g. Arianespace

12. Ariane 5
a. multiple payloads; communications satellites
b. 39,600 lbs. to LEO, 15,000 lbs. to GTO
c. 1996
d. contracts pending for 1996
e. two large solid boosters, a cryogenic core, and a hypergolic upper stage
f. 788 tons
g. Arianespace

INDIA

In 1980, India became the seventh country in the world to orbit a satellite. The nation's space research organization is developing a cryogenic upper stage to replace the upper stages of its Polar Space Launch Vehicle. With this improvement, the launch vehicle, expected to debut in 1997 or 1998, will give India the ability to launch its own communications satellite to GTO.

13. PSLV
a. remote sensing satellites
b. 6,640 to LEO, 2,200 lbs. to high-inclination orbits
c. 1993
d. 6/10 (for family, since 1979)
e. two solid stages, two hypergolic stages, and six solid strap-ons
f. 303 tons
g. Indian Space Research Organization

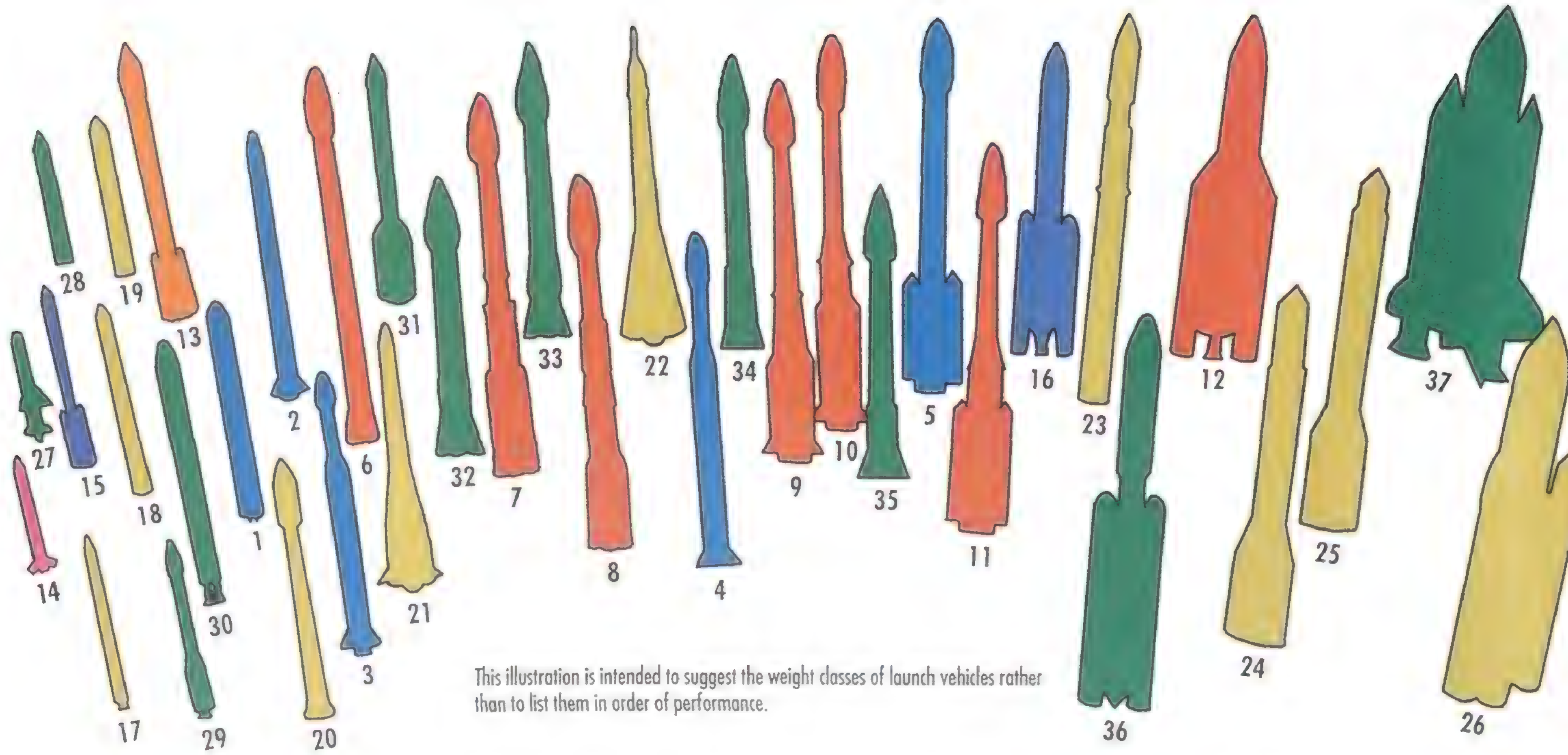
ISRAEL

The most recent country to join the space club, Israel launched its first satellite in 1988. The launch vehicle is a modified Jericho II IRBM.

14. Shavit
a. small communications, reconnaissance, and scientific satellites


ZENIT
ARIANE 5
PROTON
D-1
SPACE SHUTTLE
TITAN IV
PROTON
ENERGIA
ENERGIA

ROCKET WORLD



This illustration is intended to suggest the weight classes of launch vehicles rather than to list them in order of performance.

b. 350 lbs. to LEO
c. 1988
d. 3/3
e. three solid stages
f. 33 tons
g. Israel Aircraft Industries

JAPAN

Japan's Institute of Space and Astronautical Science (ISAS) manages the M series launch vehicles, which grew from a program of sounding rockets. The current version, M-3SII, launched two probes to Halley's comet in 1985. ISAS plans to develop the next M launcher, M-V, to carry 4,800 pounds to LEO and small spacecraft to the moon.

The National Space Development Agency manages the H-2 launch vehicle, which lifts applications satellites. NASDA started launch operations in 1975 with a U.S.-licensed copy of the McDonnell Douglas Delta and has gradually developed its own experience and technology. The H-2 is a completely Japanese vehicle.

NASDA is developing a new all-solid vehicle, the J-1, which will launch a scale model of what the Japanese plan as a reusable orbiter. The suborbital flight test is scheduled for this year; an orbital flight on the J-1 is not expected until 1997.

15. M-3SII
a. scientific satellites, interplanetary probes
b. 1,700 lbs. to LEO, 380 lbs. to escape Earth orbit
c. 1985
d. 20/23 (for family, since 1970)
e. three solid stages and two solid strap-ons
f. 68 tons
g. Nissan Motor Company, Ltd.

16. H-2
a. communications and remote sensing satellites
b. 22,100 lbs. to LEO, 8,840 lbs. to GTO, 4,420 lbs. to GEO
c. 1994
d. 12/12 (for family, since 1986)
e. two cryogenic stages and two solid strap-ons
f. 286 tons
g. Mitsubishi Heavy Industries Ltd.

RUSSIA & UKRAINE

Russia is the world leader in launch operations, having launched the first satellite, Sputnik, in 1957, as well as more satellites than any other country. But because of inexperience in Western business practices, internal political instability, and a U.S. policy of limiting launches of U.S. satellites on Russian rockets, Russia has had only a tiny share of the world launch market. Several Russian and Ukrainian design bureaus, trying to increase that share, have recently formed joint ventures and signed marketing agreements with U.S. and German aerospace companies.

17. Start-1
Russia's smallest launch vehicle is based on an ICBM that entered service in the 1970s. A five-stage version, designed to lift 1,260 pounds to LEO, failed on its first attempt last March.
a. small communications, remote sensing, and scientific satellites
b. 790 lbs. to LEO
c. 1993
d. 1/2 (for family, since 1993)
e. four solid stages and a solid post-boost stage for insertion into orbit
f. 50 tons
g. Moscow Institute of Heat Technology

18. Kosmos
In January 1995 Kosmos became the first Russian rocket to launch a U.S. satellite, a small comsat that it carried in addition to its primary payload, a Russian navigation satellite.
a. multiple payloads, communications, and navigation satellites
b. 3,700 lbs. to LEO
c. 1964
d. 405/440
e. two hypergolic stages
f. 120 tons
g. designed by NPO Yuzhnoye, produced by PO Polyot

19. Rokot
Based on the SS-19 ICBM, Rokot is expected to enter commercial service in 1997. Daimler-Benz Aerospace of Germany will market the vehicle internationally under the name Eurorokot.
a. communications and scientific satellites
b. 4,100 lbs. to LEO
c. 1994
d. 1/1
e. three hypergolic stages
f. 117 tons
g. Krunichev State Research and Production Space Center

20. Tsyklon
a. electronic intelligence and other medium-weight military satellites
b. 8,000 lbs. to LEO
c. 1977
d. 233/245 (for family, since 1966)
e. three hypergolic stages
f. 204 tons
g. NPO Yuzhnoye, Ukraine

21. Molniya
Molniya and Soyuz launch vehicles descended from the Soviet Union's first ICBM, the SS-6 Sapwood, which also served as the world's first orbital launch vehicle in 1957. Molniya launched the Soviet Union's interplanetary missions in the 1960s, including most of the Luna projects and the world's first Mars probe.
a. communications and early warning satellites; historically, planetary and lunar missions
b. 3,500 lbs. to "Molniya" elliptical orbit
c. 1961
d. 287/317
e. three cryogenic stages and four cryogenic strap-ons
f. 337 tons
g. Central Specialized Design Bureau

22. Soyuz
Soyuz is the most frequently flown launch vehicle in the world; it achieved a peak launch rate of 45 missions a year in 1978, 1979, and 1980. It has launched every Soviet and Russian manned mission since 1964.
a. manned missions, recoverable photographic reconnaissance satellites
b. 15,250 lbs. to LEO
c. 1963
d. 1,036/1,111
e. two cryogenic stages and four cryogenic strap-ons
f. 341 tons
g. Central Specialized Design Bureau

23. Zenit
The Ukrainian Zenit was designed in the 1980s as the Soviet Union's modern, all-purpose military launch vehicle. It is now the centerpiece of the Sea Launch Company, a joint venture involving NPO Yuzhnoye—Zenit's manufacturer—Boeing Company, RSC Energia, and Kvaerner Group of Norway. The company was formed to provide launch services from an offshore platform. Hughes Space and Communications has ordered 10 launches; the first is scheduled for 1998.
a. communications and electronic intelligence satellites
b. 30,370 lbs. to LEO, 8,440 lbs. to GTO
c. 1985
d. 21/24
e. two or three cryogenic stages
f. 494 or 513 tons
g. NPO Yuzhnoye, Ukraine

24. Proton (D-1-e)

The four-stage Proton took over interplanetary missions from Molniya in the 1970s and launched the Vega mission to Venus and Halley's Comet and the Phobos mission to Mars. It is currently being offered for commercial launches by International Launch Services, a partnership between Lockheed Martin Missiles & Space and Krunichev State Research and Production Space Center.

a. communications satellites, interplanetary probes
b. 10,280 lbs. to GTO; 4,400 lbs. to GEO
c. 1967
d. 205/236 (for family, since 1965)
e. three hypergolic stages and one cryogenic stage
f. 759 tons
g. Krunichev State Research and Production Space Center and Rocket Space Corporation Energia

25. Proton (D-1)

The three-stage Proton has launched every Salyut and Mir space station module into LEO.

a. communications satellites, space station modules
b. 46,200 lbs. to LEO
c. 1968
d. 205/236 (for family, since 1965)
e. three hypergolic stages
f. 740 tons
g. Krunichev State Research and Production Space Center

26. Energia

Designed to launch the Russian space shuttle, Buran, and other very heavy payloads, Energia is the world's heaviest launch vehicle. Its four strap-on boosters are the first stages of Zenit launchers. Although the Energia is not in production, the manufacturer still has an international marketing representative in the United States, NPO Energia Ltd.

a. very heavy payloads, interplanetary probes
b. 232,000 lbs. to LEO, 41,990 lbs. to GEO with upper stage
c. 1987
d. 2/2
e. four cryogenic strap-ons (Zenit first stages), a cryogenic core, and optional cryogenic upper stages
f. 3,960 tons
g. Rocket Space Corporation Energia

UNITED STATES

Of the seven types of launch vehicles operating in the United States today, three—Atlas, Delta, and Titan—evolved from ballistic missiles invented at the dawn of the space and arms race. These three launchers and the U.S. Air Force Thor carried most of the U.S. military, space, and commercial satellites through the 1960s and '70s. They were supplemented by three vehicle types no longer in operation. The Redstone-Jupiter family, which launched the first U.S. satellite in 1958 and the first U.S. astronaut, Alan Shepard, in 1961, was also based on U.S. Army ballistic missiles. The Saturn series of launchers were developed for the Apollo and Skylab missions and flown between 1964 and 1975. Scout, the country's first all-solid fuel launch vehicle, orbited more than 100 small satellites predominantly for the Department of Defense and NASA between 1960 and 1994. In the 1950s, the United States also operated the U.S. Navy Vanguard, which had a short, troubled career. More recently EER Systems offered its Conestoga vehicle, but last year its first launch attempt failed, and the company currently has no launches under contract.

27. Pegasus

Pegasus was the first all-new U.S. launch vehicle since the space shuttle. The winged launcher is carried to 38,000 feet by a wide-body transport aircraft and released. A stretch version, Pegasus XL, has been developed for 1,000-pound payloads to LEO but has failed on both of its initial launch attempts. The third attempt had not taken place as this magazine went to press.

a. small communications, remote sensing, and scientific satellites
b. 640 lbs. to LEO
c. 1990
d. 7/9 (for family, since 1990)
e. three solid stages
f. 20 tons
g. Orbital Sciences Corporation

28. LMLV 1

LMLV, or Lockheed Martin Launch Vehicle, uses combinations of already proven rocket stages for a small- to medium-launch capability. LMLV1 stacks a United Technologies ORBUS 21D second stage on a Thiokol Castor 120, a large solid rocket motor based on the first stage of the MX/Peacekeeper ICBM. LMLV 2 will use an additional Castor 120 to yield a three-stage booster. LMLV 3 will add two to six Castor IVA strap-ons.

a. small communications and scientific satellites
b. 1,800 lbs. to LEO
c. 1995
d. one unsuccessful attempt in 1995, contracts pending in 1996
e. two solid stages
f. 73 tons
g. Lockheed Martin Astronautics

29. Taurus

Taurus stacks an unwinged Pegasus atop a Thiokol Castor 120.

a. small communications, remote sensing, and scientific satellites
b. 2,870 lbs. to LEO, 1,100 lbs. to GTO
c. 1994
d. 1/1
e. four solid stages
f. 75 tons
g. Orbital Sciences Corporation

30. Titan II SLV

Titan II was the launch vehicle of the Gemini program and launched the Clementine lunar probe in 1994. Later Titan models launched Viking spacecraft to Mars and the Voyagers on their tour of the outer solar system as well as most large U.S. military payloads for three decades. Lockheed Martin is refurbishing 55 Titan II ICBMs deactivated in the mid-1980s as Titan II Space Launch Vehicles.

a. military and scientific satellites
b. 4,800 lbs. to polar orbit
c. 1988
d. 176/189 (for family, since 1964)
e. two hypergolic stages
f. 169 tons
g. Lockheed Martin Astronautics

31. Delta II

The first Deltas stacked Navy Vanguard second and third stages on the first stage of a Thor IRBM. McDonnell Douglas gradually upgraded the Delta through 16 subsequent models and added as many as nine solid strap-ons.

a. GPS, communications, and scientific satellites
b. 11,130 lbs. to LEO, 4,020 lbs. to GTO
c. 1990
d. 217/229 (for family, since 1960)
e. one cryogenic stage, one hypergolic stage, one solid stage and nine solid strap-ons
f. 254 tons
g. McDonnell Douglas Space Systems

32. Atlas I

Atlas is America's oldest space launch vehicle. Originally manufactured by General Dynamics, it evolved from the Atlas ICBM and has retained its unique one-and-a-half-stage configuration—comprising two booster engines and a sustainer engine—through almost four decades of launches.

Atlas launched the world's first comsat, SCORE, in 1958, was man-rated for the Mercury program and launched John Glenn into orbit in 1962, and sent unmanned probes to the moon, Mars, Venus, and Mercury, and—with the Centaur upper stage—Jupiter and Saturn.

Lockheed Martin is now upgrading the Atlas by substituting a single, more powerful engine for the signature one-and-a-half stage and strap-ons. Atlas IIAR is being designed to lift 8,400 lbs. to GTO.

a. communications, scientific, and remote sensing satellites
b. 12,350 lbs. to LEO, 4,970 lbs. to GTO
c. 1990
d. 243/278 (for family, since 1958)
e. one-and-a-half cryogenic lower stage and one cryogenic upper stage
f. 181 tons
g. Lockheed Martin Astronautics

33. Atlas II

a. communications, scientific, and military satellites
b. 14,500 lbs. to LEO, 6,200 to GTO
c. 1991
d. 243/278 (for family, since 1958)
e. one-and-a-half cryogenic lower stage and one cryogenic upper stage
f. 207 tons
g. Lockheed Martin Astronautics

34. Atlas IIA

a. communications, scientific, and military satellites
b. 15,050 lbs. to LEO, 6,710 lbs. to GTO
c. 1992
d. 243/278 (for family, since 1958)
e. one-and-a-half cryogenic lower stage and one cryogenic upper stage
f. 207 tons
g. Lockheed Martin Astronautics

35. Atlas IIAS

a. communications and scientific satellites
b. 19,050 lbs. to LEO, 8,150 lbs. to GTO
c. 1993
d. 243/278 (for family, since 1958)
e. one-and-a-half cryogenic lower stage, one cryogenic upper stage, and four solid- strap-ons
f. 258 tons
g. Lockheed Martin Astronautics

36. Titan IV

Titan IV was originally developed for the Department of Defense as a backup for the space shuttle in the 1980s; it has since become the Air Force's mainstay for heavy payloads. Lockheed Martin plans a solid rocket motor upgrade that will provide a 25 percent increase in the Titan IV's current performance.

a. communications and military reconnaissance satellites
b. 39,100 lbs. to LEO, 10,000 to GEO
c. 1989
d. 176/189 (for family, since 1964)
e. two hypergolic stages, two large solid strap-ons, and a variety of optional upper stages
f. 1,022 tons
g. Lockheed Martin Astronautics

37. Space Shuttle

The Space Shuttle is the only operational reusable launch vehicle in the world. There are four orbiters in the fleet. By the end of 1995, *Columbia* had flown 18 missions, *Discovery* had flown 21 missions, *Atlantis* had flown 15 missions, and *Endeavour* had flown 9 missions. The shuttle has experienced one launch failure. In 1986 *Challenger* broke apart during first-stage ascent, killing all seven astronauts aboard.

a. manned missions, interplanetary probes, and scientific and communications satellites
b. 55,000 lbs. to LEO, 13,000 lbs. to GTO with a perigee kick motor
c. 1981
d. 72/73
e. two large, solid boosters and a cryogenic core (satellites and space probes use a solid boost motor)
f. 2,244 tons
g. Rockwell International

There are really only two weather forecasts for equatorial Kourou: rain in the mid-80s or humid sunshine in the mid-80s, and if one is wrong, it's only for a short while. Liftoff was set for December 15, 1979, and in the preceding months, operations engineers Guy Dubau and Mathias Trotin busied themselves preparing the launch facilities, a task Trotin describes as "a little bit stressful. It was more complicated than the launcher, which might have one computer. The facilities have hundreds." And not all of them worked.

In an exercise to test the automated fueling of the third stage, a computer malfunction forced technicians to seize control of the operation manually. Trotin watched his associates, novices to this kind of crisis, calmly close the oxygen-hydrogen tanks and then repressurize them—extremely delicate operations. Afterward, Trotin praised the senior technician for his cool. "Thank you," the tech replied, "but what you didn't see was my heartbeat hitting 140."

Repairs were made, but there was still a ghost in the machine. During the launch countdown, the first-stage engines lit up beautifully, but a pressure gauge failed to register ignition. The ops team waited the three seconds for the gauge to cycle to its second reading—still nothing. They immediately shut everything down. Launch day excitement turned into anxiety after an investigation revealed traces of an explosion in the small pipes of the pressure gauge. Repairs would take time. Representatives from subcontractors said the problem would have to be fixed in seven days; after that the fuel and nitrogen tetroxide oxidizer from the first and second stages would corrode through the tanks, and not only would the rocket be lost, but a toxic spill would poison the surrounding environment.

Dubau, who thought the reps were being overly cautious, did his own calculations and came up with eight days. "I told everybody we had 192 hours to fix things," he says. The engineers and technicians worked straight through the next 189. With three hours to spare, the rocket was ready to fly on December 23. But the weather had turned foul, pushing the launch back another 24 hours. Finally, on Christmas eve—two days beyond the safety limit stated by the reps, one beyond Dubau's—the unshaved, unwashed, and exhausted crew watched as Ariane 1 achieved ignition, liftoff, flight, and, ultimately, geostationary transfer orbit, where it deployed a small test capsule. The entire rocket succeeded in one test. Says Dubau: "It was a miracle."

That Arianespace went on to capture nearly two-thirds of the world's commercial launch market was less a miracle than a combination of shrewd business sense, fortuitous timing, and a series of missteps by NASA—especially the last. To cede the commercial launch market to a challenger, "NASA couldn't have developed a more efficient plan," says Bruce Berkowitz, a U.S. space industry analyst. The pitfall lay in the agency's desire for the shuttle to serve everyone. This was a worthy goal, but the costs of shuttle turnaround operations turned out to be steeper than anticipated, forcing NASA to court primarily repeat customers. For all practical purposes, that meant the Department of Defense.

"In order to make the shuttle cost-effective, NASA got DOD payloads committed to riding aboard," says Berkowitz. "But getting in bed with DOD is like getting in bed with a horny elephant—not only are you going to do it, you're going to do it his way." Configurations and parameters that the defense department required frequently did not match what civilian clients wanted, which, as McCaskill and Ormsby discovered, became the civilians' tough luck. Worse, DOD's status as preferred customer put a military mission at the front of the line any time it wanted. "We had trouble getting manifested for a mission," says McCaskill.

Still, NASA couldn't afford to completely alienate every potential user. As compensation for the lousy service, the agency tantalized commercial clients with a low price. In the late 1970s, Intelsat was paying about $38 million for a launch on an Atlas Centaur. NASA, Ormsby recalls, was hawk-

Mathias Trotin (above), who oversaw the fueling of Ariane 1's third stage, described the launch preparations as "a little bit stressful." But in the end, the first test launch was a resounding success.

In 1978 Raymond Orye was sent to the United States to drum up business. His sales pitch worked—both Intelsat and GTE signed up.

ing the shuttle at $25 million. At that rate the shuttle would lose money, with the difference coming out of the U.S. treasury. "They were lying to themselves and to the rest of the world about what it was costing to use the shuttle," says McCaskill. "If the American taxpayers had really known what was going on, they'd have screamed bloody murder."

Even worse, NASA's lowball pricing all but killed the market for U.S. expendable launch vehicles, clearing the way for Ariane to come chugging in with its "old" technology. Throughout the 1980s, as clients found NASA increasingly not worth the hassles—even at cheap prices—they looked to Arianespace. The company's market opened up even further when the shuttle *Challenger* was destroyed on January 28, 1986. After that, few of NASA's limited slots could be used for commercial payloads.

D'Allest is among the first to admit that despite his and his colleagues' foresight and hunches, much of which panned out, NASA's shuttle policy gave Ariane an enormous boost into the market. "It would have been much more difficult for us to compete against the Atlas Centaur," he says. Especially when Ariane, despite its impressive debut, still had a few things to learn about the launch business. One was how to deal with customers' problems. McCaskill and Ormsby say the first launch did bear uncomfortable resemblances to working with NASA. Ariane used the European standard of electric power—50 hertz, 220 volts—whereas Intelsat's spacecraft used the American standard of 60 hertz, 110–220 volts. "They wanted us to convert to their standard," says McCaskill. "I had to take them aside and say, 'Look, you ought to be thinking of what you can do to attract more American customers down the road.' It took a while, but they came around."

"He's right," says a former Ariane engineer who worked the first Intelsat mission. "We were amateurs with customers." But they quickly became pros. McCaskill and Waylan say customer service at Arianespace has been first class for many years now.

The other lesson involved equipment testing, or rather the lack of it. The second Ariane test launch in Kourou failed due to combustion instability in one of the first-stage engines. "That was directly attributable to insufficient testing," says McCaskill. "I had many battles with them on this subject." Of the first 18 launches, four were failures. "Finally they got religion and started really examining every bit of data they had and doing enough [ground] testing," says McCaskill. The company's success rate now hovers around 96 percent.

In fact, Arianespace has grown so formidable, its grasp of the market so dominant, that now three U.S. companies—McDonnell Douglas, Lockheed Martin, and Boeing—are investing millions of dollars in their own launch programs with the hope of dethroning the king. If they wish to succeed, they would do well to emulate Arianespace's plan of starting simple and growing steadily. As Ariane 1 became Ariane 2, 3, and eventually 4, the capability of the rocket increased tremendously, as did its flexibility. To satisfy different performance requirements, Ariane 4—with the addition of strap-on boosters—can be configured six different ways. But the hardware of Ariane 4 is not appreciably different from that of its progenitor. This is about to change with Ariane 5, the first launch of which is scheduled for May. The new rocket was originally designed to take Hermes, a European shuttle, into space, but the Hermes project was abandoned in 1992. So what will Arianespace do with the 5's ability to loft heavy loads?

"It's a big mistake," believes Ormsby. "Where are they going to get the customers?" He's referring to the current NASA trend toward smaller, cheaper spacecraft and missions.

Ralph-Werner Jaeger, now senior vice president of marketing for Arianespace, disagrees. "This trend in my view is bankrupt," he says, "because space doesn't allow you to do things small and cheap. I talked the other day with [a customer] who's talking about four- to five-ton satellites in the future. In fact, I'm even concerned that Ariane 5 may be too small." Of the highly successful Ariane 4, he points out that commercial demand forced the development of its six configurations. "The same will happen with Ariane 5," he says. "You will see many versions of it. Just wait ten years."

ARIANESPACE'S SUCCESS WAS LESS A MIRACLE THAN A COMBINATION OF SHREWD BUSINESS SENSE, FORTUITOUS TIMING, AND A SERIES OF MISSTEPS BY NASA—ESPECIALLY THE LAST.

Out From the Shadow

Building the space shuttle's solid rocket motors is exacting work. At Thiokol Corporation, memories of Challenger *make it all the more demanding.*

by James R. Chiles

Photographs by Chad Slattery

A space shuttle's solid rocket motor dominates Thiokol Corporation's Rocket Garden in Utah. It was a solid rocket that caused the Challenger *disaster in 1986; today a redesigned booster keeps the shuttles flying.*

Tourists visiting the national monument at Promontory Point, Utah, the site where the Union Pacific and Central Pacific Railroads met back in 1869, can find a bonus attraction just seven miles away. It's Thiokol Corporation's "Rocket Garden," an outdoor display packed with full-size missiles and rockets from the company's long history of solid-fuel rocketry.

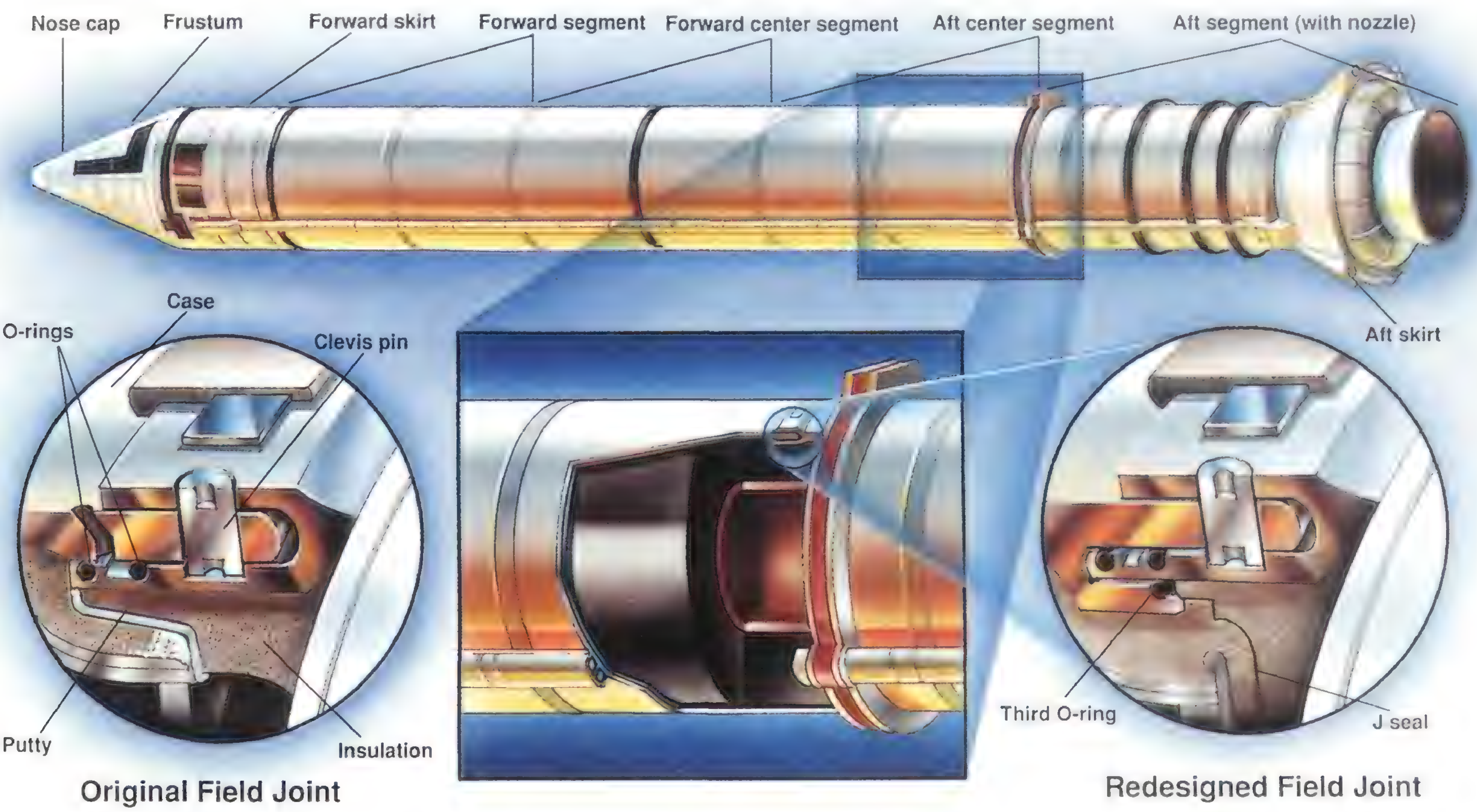
On a windy Saturday last November I had the rockets all to myself. Though it was tolerably warm in the desert sun-

Officials at NASA and Thiokol long knew that there were problems with the SRB field joints. The cold temperatures that the Challenger *was subjected to on the pad at Kennedy Space Center (left) exacerbated a bad situation.*

shine, the rockets' shadows created a distinct chill. The biggest shadow was thrown by Thiokol's most famous product, the space shuttle's solid rocket motor. The motor rested on two supports, pointing to the southeastern sky as if drawing a bead on low Earth orbit. Its shadow loomed across Thiokol's motors for the Minuteman, Trident, and Peacekeeper missiles, the boosters for the early Bomarc and Matador missiles, and the Hermes, the world's first big solid-fuel rocket and the rocket that put Thiokol, which spent its early years as a small-time producer of synthetic rubber, squarely in the missile business.

Today the shuttle's solid rocket motor is Thiokol's biggest single product line, providing nearly half of its $957 million in annual sales for 1995. The most powerful solid rocket motor in production, it is also the only one rated for human flight. Yet it's a rocket that casts a shadow, this one metaphorical, over the Thiokol company. For it was a failure in a solid rocket's field joint O-rings 10 years ago that caused the destruction of the space shuttle *Challenger* and the death of its seven crew members.

Thiokol gets its name from the Greek words for sulfur and glue, two substances used by Kansas City chemist Joseph Patrick when he attempted to create a new type of antifreeze in April 1926 and stumbled onto a formula for an artificial rubber. An offshoot of that foul-smelling substance eventually found use as a liner for aircraft self-sealing fuel tanks during World War II. After the war, the California Institute of Technology's Jet Propulsion Laboratory started using a Thiokol liquid rubber as a binder—the glue that holds together the oxidizer and fuel powders that burn to produce thrust inside a rocket casing—for solid rocket fuel. The Thiokol company decided to exploit this toehold in the rocketry field, and in 1949 it began making 75-pound infantry-support rockets at the Redstone Arsenal near Huntsville, Alabama. Within 10 years Thiokol had its own factory on a huge spread in northern Utah and was pouring 55,000-pound first-stage solid motors for the Minuteman ballistic missile. In 1974 the company won the con-



After a shuttle launch the solid motors parachute into the Atlantic, where they are recovered by ship (left). Back on shore (below) they will be inspected, taken apart, and shipped back to Thiokol for refurbishment.

tract to produce solid rocket motors for the space shuttle; eight years later it was purchased by a corporate entity originally known as a salt producer, and it acquired the name it was known by at the time of the *Challenger* accident—Morton Thiokol. (Since the accident, the company has split, with the aerospace and military business coming under Thiokol and the commercial operations under Morton International.)

In the years since the loss of *Challenger*, Thiokol has sought a measure of redemption for its role in the disaster. In the two and a half years that the shuttle fleet was grounded, Thiokol redesigned the field joints that caused the accident, and the modifications have kept hot gas from the O-rings on every flight since *Challenger*. Today Thiokol expresses confidence that shuttle launches will be using its solid rocket motors at least through the year 2010. "With that one caveat—the little word 'successful,'" says Chuck Speake, vice president of advanced programs for Thiokol's space operations. "We're all very sensitive to that. We get a report card on each launch, seven times a year. I'm generally not superstitious but I still cross my fingers at every launch. Another failure would have a severe effect on manned spaceflight."

As I toured facilities at Kennedy Space Center in Florida and Thiokol's plant in Utah to see the work involved in taking the used motors and refurbishing them for another flight, people there told me the secrets of success: Never let the preparations become routine. Never assume the equipment, stressed so hard and flown so high, is reliable. Test and test again. "It's repetitive but never routine," said Speake. "Never."

Each solid rocket that Thiokol supplies to NASA is, reduced to essentials, 550 tons of propellant poured into four separate segments. The propellant has the color and texture of a pencil eraser. A tapered manhole-like space runs down the center, widening near the nozzle end. To enable transport by rail to Kennedy Space Center, the segments are not joined until they arrive in Florida. There they are fastened together to form a long steel case closed at one end and fitted with a nozzle at the other. The assembly is now a solid rocket motor. When mated with the nose cap, aft skirt, and other hardware managed by USBI (formerly United Space Boosters Inc.), the entire assembly becomes a booster.

The segments fit together at "field joints," so named because they are made in the field—at Kennedy—rather than at Thiokol. In the doomed *Challenger*, hot gas burned its way past the joint's protective O-rings and through the motor's steel casing. Within seconds the hot exhaust had burned through a strut attaching the booster to the external tank and through the external tank itself. Aerodynamic forces quickly tore the crippled spacecraft apart.

The motor also uses a different kind of connection, called factory joints, at the spots where Thiokol fastens two empty cylinders together to make a single segment. The insides of factory joints are completely blanketed with thick rubber insulation before propellant is poured, so leaks are virtually impossible. Field joints are more difficult to make leakproof because the segments have already been loaded with fuel when they are joined, so that kind of insulation can't be applied.

In each 628-ton motor that Thiokol supplies, there are only two moving parts: a "safe and arm" device that rotates as part of the countdown sequence, and the nozzle, which can swivel up to eight degrees for steering. Once ignited, the booster's thrust cannot be turned up or down, or even turned off. It's all or nothing at all.

The shuttle's three liquid-fuel engines ignite first. Once they have reached full power, at the instant called "T-zero," a series of igniters at the top of each mo-

tor touches off the solid rocket by projecting a jet of flame along the central core. Within a quarter of a second the propellant (mostly aluminum powder and oxygen-rich ammonium perchlorate) is on fire down its full length. The 5,700 degrees Fahrenheit flame from the boosters is hot enough to boil steel, but the insulation prevents the motor's half-inch-thick steel casing from reaching a temperature higher than 130 degrees. The burning also creates great pressures, to nearly a thousand pounds per square inch, which the casing must be strong enough to contain.

After an electronic command blows apart the eight explosive nuts holding the boosters to the launch platform, the shuttle begins its climb, pushed upward by over a million pounds of thrust from the main engines and six million pounds of power from the solids. Each solid rocket burns about five tons of propellant per second, producing twin columns of white fire that outshine the pale blue glow from the main engines. Some two minutes after liftoff, with the shuttle at an altitude of 24 miles and moving just over 3,000 mph, the boosters' work is done. Small separation motors fire to peel them off the external tank. The boosters fall freely until huge parachutes slow them to a splashdown in the Atlantic far over the horizon from Kennedy Space Center. The shuttle's main engines continue running for another six minutes. Then the empty external tank separates and tumbles away to break up and splash into the Indian Ocean.

The external tank is the only major piece of the shuttle not preserved for reuse. Virtually all of the rest will fly again, down to the steel pins that connect the motor segments at the field joints and the rubber flex joint that allows the nozzle to swivel back and forth. Thiokol estimates that reusing the metal booster parts instead of buying all new pieces each time cuts each mission's cost by $42 million.

Currently the metal cylinders making up the motor are rated for 20 total flights, but that's probably low, according to Ken Jones, the solid rocket motor chief engineer for NASA's Marshall Space Flight Center in Alabama. Thanks to advances in refurbishment, the metal is being better preserved than planners had expected. "Some of us believe that we can use them a lot more than 20 times," says Jones, who has been with the shuttle program since 1971.

Following *Challenger*, there had been talk about welding the metal casing into a single tube, eliminating the joint seals and, perhaps, ending the policy of reuse. Indeed, welded joints might have prevented the *Challenger* accident, but today's joints are much more sophisticated than those on *Challenger*'s boosters. The people I talked to at Thiokol believe strongly that—aside from the cost issue—recovery and reuse is safer than starting with new equipment each time. "You'd still have to have all the same inspections on new parts," said Glenn Caporale, refurbishment chief engineer

"Our position is that no O-ring damage is acceptable," says Thiokol's Mike Kahn (above).

At the Promontory plant, plastic tubes provide emergency exits in case fire threatens to ignite propellant.

"I'm generally not superstitious but I still cross my fingers at each launch," says Thiokol's Chuck Speake.

at Thiokol's Clearfield center. "It's not only cheaper, the information you get back is invaluable."

Still, the solid rocket boosters don't survive unscathed. Sometimes SRB segments will crack when hitting the sea or during towback. Corrosion can pit metal surfaces, and the stresses of launch and recovery can bend the round metal cylinders slightly.

I asked Robert Hotz, former editor in chief of *Aviation Week & Space Technology* and a member of the commission that investigated the *Challenger* accident, if he thought SRB reuse had created safety problems. "Not particularly," he said. "What bothered us was the lack of information going up the line on what was being discovered after recovery of the SRBs. The people at the top never heard some of this stuff."

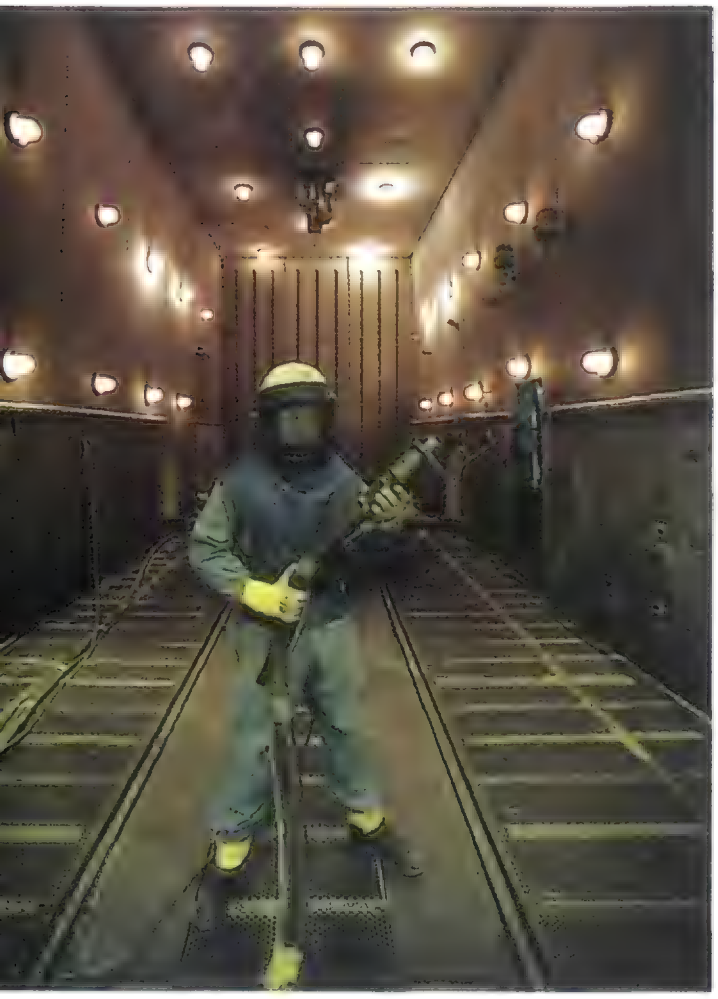
Even before the shuttle begins its climb into space, the recovery process has begun. A full day before launch two recovery ships cast loose from their docks at Canaveral Air Station and head down the Banana River and out to sea. These ships, the *Liberty Star* and the *Freedom Star*, are designed to handle everything a booster leaves floating in the Atlantic: three main parachutes, a nose section called a frustum, which looks like an Apollo-era capsule, and the long steel casing. NASA owns the ships and contractors run them. Thiokol ran them until October 1995, when NASA shifted the work to Lockheed Martin Space Operations as part of that company's overall processing contract at Kennedy. NASA sends along two or more employees on each voyage, as does USBI.

The ships take up stations at least 100 miles from the Cape. On clear days the crews can watch the whole launch, from climb-out to booster splashdown. Four loud sonic booms announce the boosters' approach.

"This is a kick-butt operation," Wayne Ranow, booster retrieval and disassembly manager for NASA, told me when I visited him in his office at Hangar AF in the Cape Canaveral Air Station. At an average cost of $71,641 per voyage, Ranow said, "It's pretty cheap to go out and get 'em."

That cost covers a three-day round trip, but sometimes it takes longer. STS-63, *Discovery*'s mission to approach the Russian *Mir* space station in February 1995, provided one of the toughest booster recovery trips. The boosters splashed down some 140 miles east of Jacksonville in seas with waves ten to 12 feet high and winds gusting to 40 knots. By the following afternoon the weather had calmed enough for the ships to snag the boosters and begin dragging them back home. Then the weather turned bad again. Rough seas broke the tow rigging behind both ships at about the same time, and the boosters settled back from horizontal "log mode" into a vertical position.

Finally, the crews managed to re-rig the boosters and resume the slow cruise back to Kennedy. By the time they reached the dock, they had spent six days at sea. The severe conditions had taken a toll on the boosters: NASA had to retire several sections because of damage on splashdown and lost an aft skirt and frustum, which broke off in the heavy seas on the way back.



Cleaning segments is a blast: Gary Swenson demonstrates the water jet (top), while Brian Compton models the uniform for the grit blast chamber.

Once the boosters are out of the water and rinsed of corrosive saltwater, the segments are separated. Technicians at Kennedy inspect the field joint seals for any signs of gas leakage as early as possible. More detailed checking awaits the segments' arrival at Thiokol's refurbishment center in Clearfield, Utah.

While showing me through one of the World War II-era structures there, Mike Kahn, vice president of production for Thiokol's space operations, pointed out some yellow caution tape surrounding nozzle segments from STS-73, a *Columbia* mission launched in October. Inspections at this stage last summer, Kahn said, revealed that exhaust gas was slipping through an insulating layer of caulking, eroding tiny pits in an O-ring between nozzle sections in one motor each from missions in June and July. The pits resembled the tiny marks that a pencil point might make. No gas got past the O-ring.

The press drew the inevitable comparisons to *Challenger*'s O-ring problem, but Kahn stressed that the nozzle problem had nothing to do with the health of the field joint O-rings, for which a completely different approach that doesn't involve caulking is used to protect the O-rings.

NASA suspended the launch of *Endeavour*, scheduled for August 5, pending investigation. Thiokol found the problem to lie in the installation of caulking, called RTV, between the nozzle segments. As the RTV oozed its way around the joint's perimeter, it sometimes left a small air pocket where the two ends of the caulk line met to complete the circle. The exhaust gas pressure at launch had opened a channel through this pocket, which reached as far as the O-ring before it stopped. Thiokol consulted with the Marshall Space Flight Center on the fix, then sent a team to Florida to scrape out an inch of the original RTV from *Endeavour*'s nozzles. Using a vacuum line to prevent air pockets, the team replaced the RTV. Checks after *Endeavour*'s launch showed no more erosion on the nozzle O-rings. "We took time out for the fix and it was no big deal," says Kahn. "Our position is that no O-ring damage is acceptable, even if it's only five-thousandths of an inch."

I couldn't help reflecting upon the change since the pre-*Challenger* days. According to the final report by the Presidential Commission on the Space Shuttle *Challenger* Accident, better known as the Rogers Commission for its chairman, William P. Rogers, "Thiokol and NASA management came to accept erosion and blow-by [of the field joint O-rings] as unavoidable and an acceptable flight risk." As early as 1977 Marshall engineers had begun distributing memos laying out their concerns that Thiokol's field joint design might not hold pressure when the booster's steel case inflated with the initial pulse of exhaust gas. Although the first

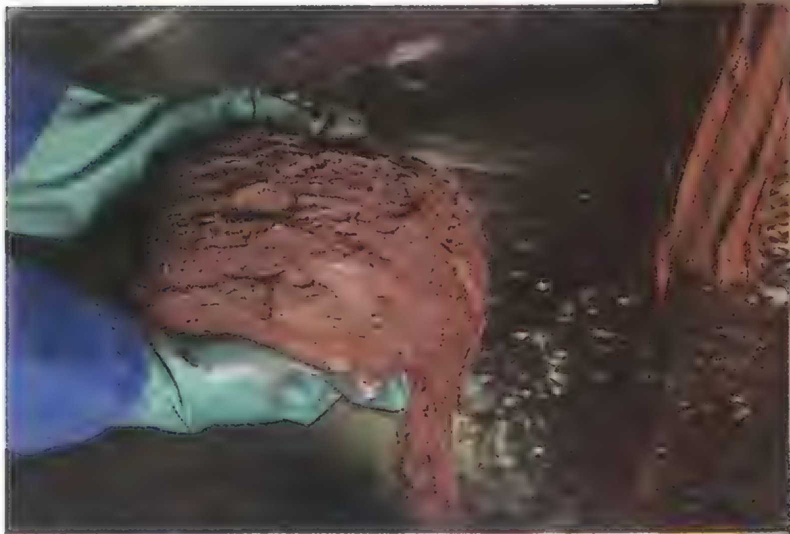
At the Clearfield center, Mitch Gittins and Kyle Nyman check to see that a segment's insulation is firmly in place. Glenn Caporale (below) stands inside tooling used for pressure-testing the refurbished segments.

10 shuttle flights showed only infrequent signs that gas was getting past the insulating putty and reaching the rubber O-rings, in 1984 things took a turn for the worse. Of the 14 missions leading up to *Challenger*'s last flight, more than half showed signs that gas was scorching the O-rings. On some flights gas had even burned its way past the first of the two O-rings, meaning that it was getting close to the surface of the case.

The commission found that the burning had worsened after modification of a preflight test that pumped nitrogen into the field joints to check for leaks. The pressure of the nitrogen had been increased, which may have opened up channels in the joints' putty that allowed exhaust gas to reach the O-rings. The commission also concluded that a thorough look at the pattern of problems would have shown a connection to cold weather, and pointed in particular to the O-ring damage on the January 1985 launch of *Discovery*, which experienced the coldest weather of any flights prior to the accident.

Marshall and Thiokol looked into the O-ring damage but could not decide on what to do.

By August 1985, the commission said, NASA management had enough clear evidence of a serious problem and should have taken action before the next flight. Yet the launches continued. Thiokol organized an engineering task force, headed by Roger Boisjoly, to fix the leaking seals. It was this task force that



Don Issacson removes a propellant sample from its mixing bowl for analysis. When dried and cured, the gooey substance will have the consistency of a pencil eraser.

led to a famous "HELP!" memo from Robert V. Ebeling to Allan McDonald of Thiokol, warning that the group was not getting the resources it needed to work out the problem.

On January 27, 1986, the night before the *Challenger* launch, representatives of Thiokol and Marshall conducted a fateful teleconference, with Thiokol engineers arguing that the cold weather at Kennedy could adversely affect the resiliency of the O-ring seals, perhaps allowing gas to leak. The teleconference ended with Thiokol managers overruling the engineers and agreeing to recommend that the launch proceed.

Ultimately, said commission member Hotz, "Morton Thiokol's role is just a detail in the accident. It was caused by NASA management. The fact is that there are many other plausible ways it could have happened."

"The guys in the space division had a lot of concerns afterward, asking themselves what could they have done better," said Carver Kennedy, who as a company vice president oversaw the redesign of the motors. "It was part of the healing process.... Some of [the engineers] retired, and a few felt uncomfortable with man-rated motors and left."

After the accident, Thiokol found itself in the media glare. It was accused of retaliating against employees Roger Boisjoly and Allan McDonald, who had opposed the launch and later had testified about that to the Rogers Commission. Boisjoly accused the company of fraud, leading to an FBI investigation that was later dropped. The company decided to drop out of the bidding to build the Advanced Solid Rocket Motor, intended to replace the motors it was producing. The company also gave up $10 million of its profits as a settlement with NASA and agreed to do the redesign and rebuilding at cost.

"It was a track meet," said Kennedy of the effort to get the shuttles flying again as soon as possible. He put Allan McDonald—who had been reinstated—in charge of the technical work. "It became a crusade for Al. Others got depressed and didn't have the same personality—they couldn't handle it. But 99 percent of the people were like Al. The attitude was: By God, we're going to fix this thing, and not just cosmetically either. We were going to do everything we needed to, and that's why we have this belt-and-suspenders approach now."

After studying the problem, Thiokol decided to replace the putty used to seal the joints with a gas barrier called a "J-seal." Other barriers guard against gas leaks in the redesigned field joints, including three O-rings and a tight fit

of metal to metal, but the J-seal is the first line of defense against hot gas. "Nothing gets past the J-seal," said Kennedy. "It's self-actuating. As long as there's pressure, the door is closed."

At the Clearfield center, refurbishment chief engineer Glenn Caporale folded back a plastic sheet taped across the end of a used motor segment and showed me one side of a J-seal as it appears after a flight. It was a grayish-green ring of rubber about four inches wide running around the inside lip of one of the segments. The only sign of use was charring of a half-inch of rubber along the inside edge. During a launch, gas pressure forces this ring against a mating surface of similar rubber on the other side of the joint. The higher the gas pressure, the harder the J-seal works to shut off gas flow.

Even seals that survive completely unmarked get stripped off the boosters in Clearfield, along with all other rubber, adhesives, and paint. Engineer Gary Swenson told me that during the first five years of the shuttle program, removing a tough rubber ring from a nozzle component called a boot was a brute-force operation, with a technician spending hours pounding on a cheese knife with a leather mallet. "It was essentially a Stone Age approach," Swenson said, showing me some of the well-worn tools. Today Thiokol uses computer-steered water jets to do the job. Swenson fired up the pumps, and water pressurized to 36,000 pounds per square inch began slashing through four inches of reinforced rubber with the ease of a sewing machine needle penetrating cloth. Only 1/30 of an inch across, the jet uses less than four gallons of water a minute. The nozzle sections also go through the grit blast chamber, where a spray of tiny glass beads removes contamination from the metal.

Once the cylinders are stripped they undergo a battery of tests. One test fills each cylinder with oil pressurized to 1,100 pounds per square inch to expose any large cracks. An eddy current test runs an electric charge through the metal to look for smaller cracks.

Another potential problem is tiny corrosion pitting, just a few thousandths of an inch deep and barely visible to the naked eye, in the steel near the O-rings. Thiokol technicians "blend" these out with a small grinder. This helps prevent formation of cracks that could weaken the motor case or offer exhaust gas an escape path under an O-ring.

Thiokol used to test rockets constantly but now fires a full-size booster on its test stand only once a year. But with two motors each for seven flights, the company gets 14 sets of results back every year. Besides finding the leak through the nozzle's RTV, post-flight checks have led Thiokol to change the way it laid up the heat-protective layer in the cowl for the exhaust nozzle, and to take extra precautions against gas leaks where the igniter joins the motor. (As this issue prepared to go to press, NASA announced that post-flight inspections had discovered scorched O-rings in the case-to-nozzle joints from the boosters that launched *Columbia* on STS-75 on February 22.)

Now filled with propellant, a segment is carefully lowered to horizontal in preparation for transport.

Keeping the entire testing procedure under tight controls is vital, yet it's a task made difficult by the slow evolution of the SRB. The motors change in subtle ways from month to month, as subcontractors go out of business or change their manufacturing lines. Other changes are driven by environmental requirements to stop using strong ozone-depleting solvents.

Consider the many seemingly minor factors that may have contributed to the *Challenger* accident. Although most wrap-ups of the accident zero in on the effects of the frigid January weather on the O-rings, a look through the Rogers Commission report turns up other factors, some rooted in design and processing: leak-check techniques that may have actually created holes in insulating putty between the segments, problems in fitting the two segments together, openings in the seals caused by the inflating effect of gas pressure on the motor case, an accumulation of stresses at the attachment strut located near the leak.

When Thiokol finishes the testing at Clearfield, the empty cylinders travel by truck to Promontory to be filled with propellant. Even without the signs at the fence advertising Thiokol's role in the space program, it would be obvious that this vast compound in the desert hills is making something unique. For one thing, wide firebreaks have been bulldozed up and over the rocky hillsides, and earthen blast-deflection berms have been placed around some of the widely dispersed buildings. And every building that holds rocket propellant or other volatile compounds has blue plastic tubes that offer a quick exit from each floor in case of fire.

As director of the final assembly work center, Guy Fowler (above) oversees the installation of the igniter, a task that requires precise tightening of 40 bolts (above right).

After still more quality checks of the cylinders, the Promontory plant joins them into the four segments that will add up to a full motor in Florida. Each segment is made up of two cylinders, except for the rearmost one, which uses three. The job of matching the metal cylinders for the best fit belongs to a group in Clearfield called the Case Assignment Team. It uses measuring instruments mounted on a rotating arm to map each ring's deviation from a perfect circle down to one thousandth of an inch. After insulating the inside of the segments, Thiokol is ready to pour the propellant.

Solid-fuel propellant is distinctly inedible, but the machinery for mixing it has a bakery in its pedigree. Propellant is stirred inside giant stainless steel mixing bowls, 7,000 pounds at a time, by machines built by a company that specializes in industrial-strength bread dough mixers. The finished mix even looks like thick cake batter. Over the course of a day 40 to 45 batches are poured into each segment, which have been placed in heated receptacles called curing pits. And as with any kitchen, somebody has to clean up afterward. At one time Thiokol workers wielded long-handled spatulas to scrape out the half-inch of propellant left in each mixing bowl, but now the job has been turned over to robots. Once the propellant is poured into the segment, it solidifies over five days of heating and curing within the pit. After the curing is finished, a machine removes a device called the mandrel from the segment, leaving the center core that runs down the propellant's center.

Each loaded segment goes back into the round of final exams: through ultrasonics to check for bond failures between insulation and metal, then into a room with six-foot-thick concrete walls for snapshots by a giant X-ray machine. This scans for cracks or voids in the fuel. After checkout, all segments meet at Building M-397 for final assembly: not the stacking of the components into a full motor, but the installation of the igniter in the forward segment and the nozzle assembly in the aft segment.

The igniter is a miniature rocket motor about the size of a trash can that bolts into the pressure dome. It takes three people to tighten the 40 bolts that encircle the igniter. Two handle the socket wrench involved, which has a handle at least four feet long and is connected to instruments that monitor torque and the wrench's position to signal the precise instant to stop tightening. Previously Thiokol used ultrasonics to check each of the 40 bolts, but the job took at least five technicians 12 hours. Now a half-hour of work is enough to tighten and check them all.

"It took four to six months to get this

Finished segments are trucked to a railroad for the trip to Florida, where they are stacked to make boosters.

qualified," said Guy Fowler, a former Air Force fighter pilot who directs the final assembly work center. He is speaking of the certification required before NASA will allow any change in such a flight-critical process. "You have to proceed very intentionally when you're thinking about making a change," he told me. "We have a controlled process now and we don't want it to get out of control. We want to make damned sure that we stay in control."

After Promontory has finished its work, the segments are ready for the railroad trip to Florida. On arrival the first stop is the Rotation, Processing and Surge Facility, which runs them through more tests and prepares them for stacking into a full-length motor. That job takes place in the Vehicle Assembly Building, a massive cube of a structure originally designed for the assembly of Saturn V rockets.

As I watched, an overhead crane plucked a motor segment off its yellow transporter as part of the stacking process. Nothing happens quickly here, because the heavy segments hold a lot of high-energy propellant and NASA considers lifting them a hazardous operation. The technicians spent well over an hour preparing for the lift, and when the crane finally began hoisting, the segment rose so cautiously that movement was hardly visible. It took 20 minutes for the segment to climb a little more than a hundred feet. Then it disappeared behind a wall of steel bracing that surrounded one of the high bays in which the solid rocket motors are pieced together.

Once the SRBs are stacked, the external tank will be attached to them. Then the orbiter itself will be lowered into place astride the huge orange tank. The two SRBs will now support the weight of the entire launch vehicle. After a battery of pre-launch tests, the shuttle stack will start its four-mile trip from the VAB to the launch pad, a journey that takes six hours.

When the shuttle launches, Chuck Speake won't be the only one with his fingers crossed. *Challenger* demonstrated that a shuttle launch is an immensely complicated and inherently risky operation: NASA now estimates that the median odds of a catastrophic accident during a mission are one in 145. The *Challenger* disaster taught Thiokol some harsh lessons. The shadow cast by the accident will never disappear, but its presence has improved the odds for future missions. As one Thiokol supervisor at Kennedy told me, "We have to do the job right every time. If we do, we get to launch one more." The next launch won't be risk-free, certainly, but perhaps it will be safer.

Air and Space

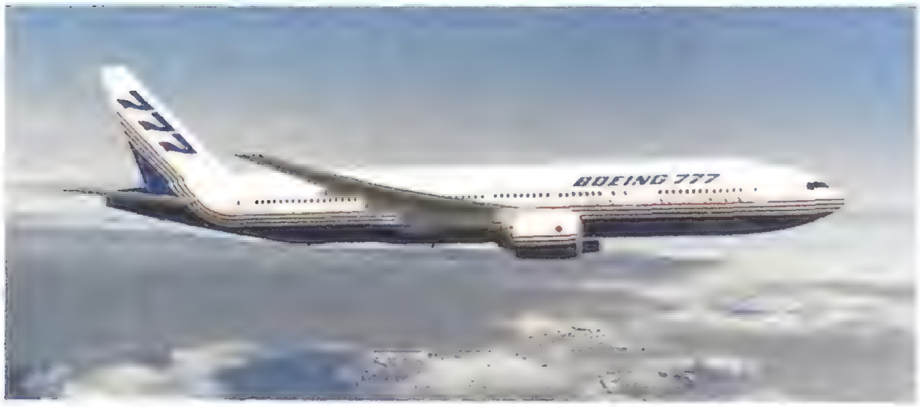
2006 Two much-discussed options for the coming decade are a new supersonic transport and an 800-passenger airliner. In fact, neither will be built.

There is very little interest among the airlines in the behemoth. Such an airliner would best suit an international hub-and-spoke structure, centered on such major gateways as Heathrow, JFK, and Narita. However, passengers don't like hub-and-spoke; they prefer point-to-point routes, such as San Francisco-Rome. The continued growth of international service, particularly in the Far East, will make it increasingly easy for airlines to offer attractive point-to-point schedules.

The airlines are also unenthusiastic about an SST. They know that a fleet of SSTs would skim off their first-class passengers, along with much business-class travel. These are the most lucrative portions, and within an industry that still would remain dominated by subsonic jets, such a development would raise hob with their fare structures. Of course these carriers faced precisely the same issue around 1955, when the first jetliners presented the same challenge to the piston-driven airliners of the day. But at that time the industry had a leader, Juan Trippe, who was strong enough to drag everyone into the jet age whether they wanted to come or not.

The most important competition of the next 10 years instead will pit the Boeing 777 against the Airbus A-330/340.

—T.A. Heppenheimer, author, Turbulent Skies: The History of Commercial Aviation



BOEING 777: PHOTOGRAPH COURTESY BOEING

2006 The general trend that will bring the most significant changes in the next decade is the proliferation of joint ventures—company-to-company and between companies and government agencies—both within and across national and continental boundaries. Corporations and business consortia can move much faster, more aggressively, more broadly, and more efficiently than governments. Their cooperation is a tremendous economic reorientation of the aerospace field, the effect of which will be to change totally the way progress is made in both commercial and government aerospace programs, including national and global security.

—Jerry Grey, Director, Aerospace and Science Policy, American Institute of Aeronautics and Astronautics

2006 I am hopeful that the next decade will demonstrate ever more clearly that for the foreseeable future, the exploration of the universe from space should and will proceed with automated spacecraft and not with humans. Although it is perhaps too much to hope that the enormously expensive space station will be canceled, that project should not obscure the growing awareness that for the next few decades at least, the only significant benefit from humans working in space is to study and to discover better ways to have humans working in space.

—Donald Goldsmith, astronomer and author

If we as human beings really desire to explore space in a manner consistent with how we have explored our own planet, we must devise some new technology that will circumvent the constraints of our standard rocket approach to orbit. Consider for a moment a delightful essay, "Romans to Mars," written in 1989 by D.J. Bents, an engineer at the NASA Lewis Research Center. Bents showed it would have been possible for Romans to row slave galleys to the new world by cleverly staging the ships. A single slave galley had a rather limited rowing range based on available food and drink. By starting a transoceanic expedition with 32 slave galleys and off-loading the supplies from half the ships onto the remaining ships at strategic points along the way (the returning ships have barely sufficient supplies for the voyage home), the remaining ships can proceed onward. By using this staging approach, it is possible for one ship to complete the voyage. Of course this exploration would be costly (it was hinted that the Roman Senate waffled on providing the necessary funding). Not until new technology emerged, with keel and sail designs which allowed upwind tacks, did transoceanic exploration become economically feasible. Yes, the Romans had the technology, but only for an engineering and economic absurdity.

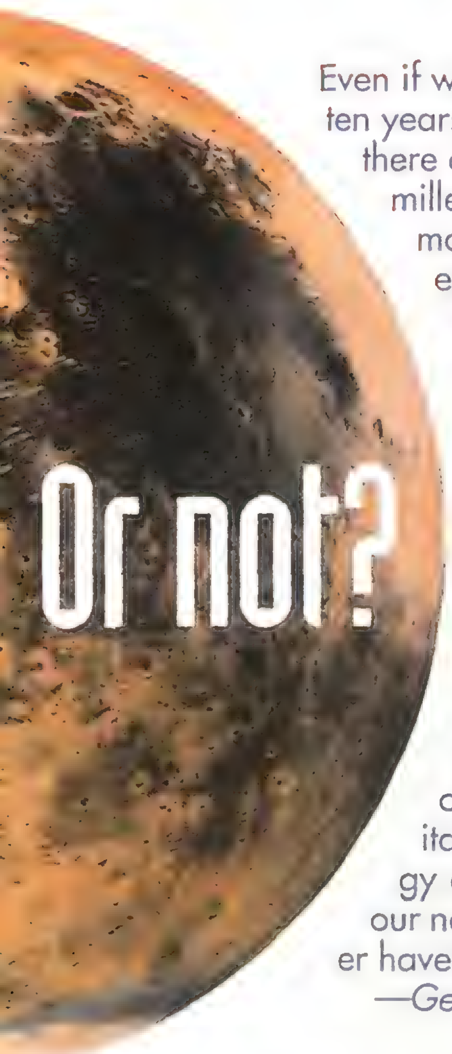
Before mankind ventures away from Earth, we must first develop the space equivalent of navigable sailing ships to replace our current rocket slave galleys.

—Donald Pettit, staff scientist, Los Alamos National Laboratory

MARS PHOTOGRAPH COURTESY NASM/CEPS

Futures

Progress in aviation and spaceflight follows no predictable path. We have nevertheless collected convincing forecasts for the next 10 years along with a few dreams of what could be.



Even if we do make it to Mars in the next ten years, we will not make regular visits there or to any other planet in the next millennium. It was once said by a famous explorer that he climbed Everest because it was there. He should have added that he was able to climb Everest because he could afford to do so.

There are those who want to go to Mars because it is there. But we cannot afford to do this in any significant manner because colonizing Mars will cost a great deal. You might counter that someone may yet invent a cheaper way to get there, but that does not avoid the harsh reality of getting mass out of Earth's gravitational influence. That costs energy and money. And given the way our nation is cutting back, we will never have that money.

—Gerrit Verschuur, radio astronomer and author

It is not generally appreciated how much of a serious effort is being made by planet Earth to explore Mars. This year three missions are scheduled for launch to Mars: two by the United States and one by Russia. In 1998 there will be three more: two by the United States and one by Japan. The United States has committed to two launches at every Mars opportunity (every two years for the next ten years). Not to be outdone, the European Space Agency is planning an Ariane launch to Mars with several landers in 2003, in addition to the U.S. launches and potential Russian ones.

The spate of missions in the next decade will bring a plethora of results about the location of any water on Mars, the interaction of water under the surface with the surface and atmosphere, the possibilities of past life on that planet, and the potential for future life. In addition, much will be learned about Mars' surface topography and geology, climate history and atmospheric processes. One would hope that by the end of the first decade of the 21st century, we will have several countries working together earnestly, preparing the first human missions to Mars. I expect that the 21st century will be the century in which we determine whether the human species is a single-planet species or a multi-planet species—and that determination will be made on Mars.

—Louis D. Friedman, Executive Director, The Planetary Society

If I had to choose just one space technology that will materially affect society worldwide in the next 10 years, I'd pick the Global Positioning System of navigation satellites. In the next 10 years, I think GPS utilization by the civilian sector will continue to explode. From hikers to boaters to people driving cars or navigating aircraft, GPS use will be ubiquitous before we know it. A recent study by the National Academy of Public Administration forecasts that GPS will be a $31 billion world market by 2005 (growing from a $2.3 billion market in 1995).

— Marcia S. Smith, Specialist in Aerospace Policy, The Library of Congress

Stealth has revolutionized warfare and has rendered current air defense systems obsolete. We will see technology development for a whole new generation of air defense systems in an attempt to counter stealth. The technology of air defense systems is relatively mature and improvements will come slowly. Stealth technology is new and in the next 10 years will advance rapidly. Thus, the capability of stealth-possessing countries will stay far ahead of other nation's defense capabilities.

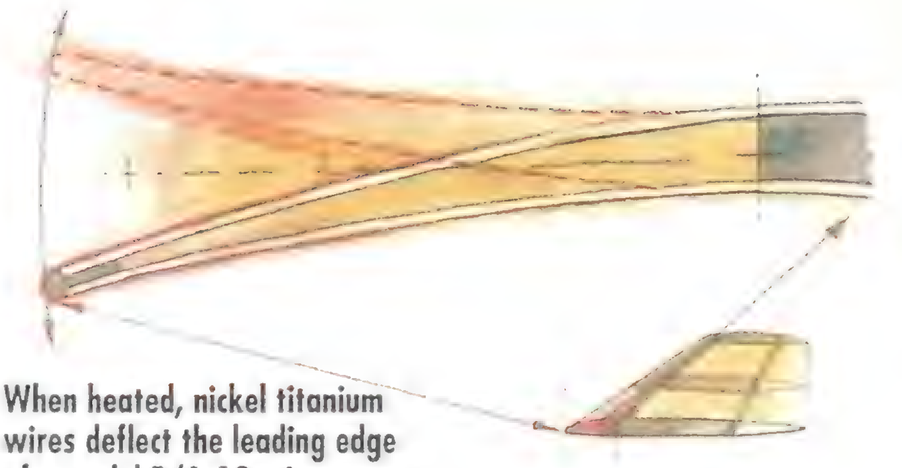
—Jack S. Gordon, President, Lockheed Martin Skunk Works

I hope we leave behind in this century the requirement that student pilots learn to fly in airplanes. Novices learning to fly with a view toward aviation as a profession should learn to fly on the ground, in a machine that replicates a turbine aircraft, probably with two engines.

The efficiencies of on-the-ground training are nearly countless: For one thing, your training starts the minute you close the door to the simulator, regardless of the weather or how crowded the airport is. For another, an endless variety of situations and emergencies can be replicated quickly, easily and safely. Also, the same maneuver can be flown over and over without wasting time to—for example—land, taxi back for takeoff, fly around the airport pattern, approach, land again and so forth.

Is it possible to learn to fly in a box? In 1970, I spent one month, entirely in a simulator, learning to fly a twin-engine Citation jet (the first jet I'd ever flown and the first airplane that big that I'd ever flown, so it was pretty much like starting all over again). I never saw the actual airplane until the day I climbed into it and took my FAA check ride, which I passed.

—Stephan Wilkinson, pilot, private airplane builder, and aviation journalist



When heated, nickel titanium wires deflect the leading edge of a model F/A-18 wing.

Air- and spacecraft that will fly ten years from now are being hatched in today's laboratories, and the trend is toward dynamic components—individual parts of an airplane or satellite that change as their environment changes. Soon the structure of a craft will participate in a mission by monitoring its environment, assessing its own health, improving its own performance, and even carrying out some of the business of reconnaissance or remote sensing. With smart structures and materials, aerospace researchers are beginning to meld the once separate concepts of form and function.

SMART WINGS

A wing that can sense changes in airspeed and pressure then alter its shape in response—without flaps, slats, hinges, spoilers, or any other mechanical control surfaces—will *not* be flying for the airlines ten years from now. But such a wing could fly on a test vehicle by that time, according to Jayanth N. Kudva, program manager of one of the latest research efforts to produce a smart wing. Kudva is overseeing a $3.4 million contract awarded to Northrop Grumman Corporation by the Advanced Research Projects Agency (ARPA) to develop a wing that will stretch, flex, and twist to grab more lift and another that will continually reshape itself during transonic cruise to maintain the most efficient contour.

Northrop Grumman is conducting two series of wind-tunnel experiments during the program. Engineers at the company's facilities in Hawthorne, California, have fabricated 1/6 scale models of a McDonnell Douglas F/A-18 wing to test the performance of shape memory alloys—flexible materials that can bend or deform and "remember" the direction and extent of the deformation. The model's leading and trailing edges curl down or flex up because of the action of a series of nickel titanium wires embedded in their upper surfaces. Nickel titanium deforms when heated. For the tests, a central processor in the laboratory configures the wing for takeoff, landing, or high-speed maneuvers by applying heat (through an electrical current, for example) to the wires. The eventual goal is for sensors in the wing itself to detect stresses or loads and to inform actuators that will configure the wing accordingly.

The Vought F-8 Crusader, which entered service in 1957, is the inspiration for another smart-wing technique Northrop Grumman is testing. The Crusader had a unique two-position, variable-incidence wing to grab a little more lift at takeoff and landing. Hung on pivots, the wing could rotate to a higher angle of attack independently of the fuselage, which remained at the normal, near horizontal level to ensure good pilot visibility. When the pilot configured the aircraft for takeoff or landing, he pulled a control lever in the cockpit that raised the wing's leading edge 7 degrees.

Northrop Grumman's idea is to twist the wing with a torque tube embedded within it. The wing root would remain level, but at the tip the leading edge could twist up or down about 5 degrees. The torque tube is also made of nickel titanium and, like the wires in the leading and trailing edges, responds to heat. No pivots, no hinges, no levers in the cockpit.

How does the wing know which way to twist? The engineers train the tube. They precondition the nickel titanium, which is rubbery when cool—"and like stainless steel when it's heated," says Peter Jardine, an engineer working on the project—by cycling it in the direction they want it to remember, say clockwise. The aluminum wing yields to the alloy tube when the tube is heated to its steely characteristics; when the tube cools, the stiffness of the aluminum forces it to untwist.

At another Northrop Grumman facility, in Bethpage, New York, Fred Austin and a team of engineers are developing a system of smart actuators that can subtly refine the cross section of a wing, as it flies, to reduce drag. At speeds just below Mach 1—the speeds at which most airliners cruise—air flowing over the wing is frequently supersonic over some portions of the wing and subsonic over others; in other words, transonic. When the airflow changes abruptly from subsonic to supersonic, a shock wave forms over the wing and creates drag. Austin's team is studying ways that sensors on the aircraft can detect the increased drag and change the shape of the airfoil slightly to smooth the air's transition.

In the Northrop Grumman design, conceptualized for a Gulfstream III wing, each wing would rely on a system of trusses. The engineers have tested the design using mechanical actuators in a full-scale model of a Gulfstream's wing section. In current tests they are experimenting with materials that deform under applied electric current and others that deform under applied magnetic fields.

Reducing drag would keep the pilot from having to step on the gas. "Our study shows that even if we added a thousand pounds [by installing the trusses] to the airplane, you could still save 5 percent fuel," says Austin. "Commercial jets used three billion gallons of fuel in 1995. That cost $7 billion. If we can make a slight dent in that, we've had an important program."

Are there worlds like the Earth around nearby stars? If so, are they habitable and is life present there? We are currently in the process of building a 25-year plan for space science, and finding answers to these questions is among our goals. We plan to search for planets and planetary systems around the nearest stars out to about 50 light years and to search for Earth-like planets, which may be habitable or inhabited, through direct detection and spectroscopic measurement.

In the beginning of the next decade, we will orbit three spacecraft to test in space very-large-baseline interferometry, a technique for mapping a source by comparing the radiation received by different detectors. In ten years or so, we should have the technology to identify planets out there like our own (if they exist) and determine if they have life.

—Dan Goldin, NASA Administrator

ILLUSTRATIONS BY WEB BRYANT

Northrop Grumman's concept places 11 trusses in a Gulfstream wing. Each truss has 14 actuators that expand and retract independently of one another to change the airfoil's shape.

SMART ENGINES

One basic principle guiding the design of jet engines is that it's best for the most part to keep the air flowing in the front and out the back—a directional pattern more difficult to assure than it would at first seem. Under certain circumstances the air being sucked through, pressurized, and directed by the blades of a jet engine's compressor can begin to pulse in its flow and even reverse direction, a phenomenon known as rotating stall and surge. The resulting loss of power can be devastating to the aircraft. To avoid compressor stall and surge, aircraft engines currently operate at lower pressure than their compressors are designed to achieve, a condition that lowers engine performance.

mart

To increase the operating capability of current engine designs, researchers at the gas turbine laboratory at the Massachusetts Institute of Technology are experimenting with sensors that detect the conditions leading to compressor stall and actuators that interrupt the developing disturbances. In the late eighties the researchers studied airflow through compressors to determine patterns they could identify as the precursors of rotating stall. Mathematicians at the Charles Stark Draper Laboratories helped to develop algorithms that would identify signatures of the disturbances. "It's important to catch the conditions early," says Alan Epstein, Associate Director of MIT's Gas Turbine Laboratory, "because the earlier you catch them the less power is required to overcome them. Although surge and stall are enormously energetic in their mature form, they both start out as very-small-amplitude, linear disturbances." Epstein uses the analogy of balancing a pencil by its point on your finger. While the pencil is close to vertical, only small motions of your finger are necessary to keep it upright. Once the pencil leans at a large angle, however, larger corrective action is required.

Epstein and his colleagues have found that rotating stall can be predicted by an array of sensors recording pressure and characteristics of airflow and prevented by actuators that dampen oscillations. The sensors pick up the speed, phase and growth rate of small pressure waves that travel around the circumference of the compressor, translate the information into a digital pattern, and send it to actuators—either air jets arranged around the outside of the compressor or small oscillating vanes in the engine's inlet—which respond with the appropriate phase and amplitude to counter the growth of the vibration.

With U.S. Air Force support, Pratt & Whitney is currently demonstrating active compressor control techniques on a prototype F119 engine, selected for the F-22. And Epstein and his colleagues at the gas turbine laboratory are continuing their research in three directions: on a large, high-speed compressor in cooperation with NASA's Lewis Research Center in Ohio, on surge control of helicopter engines, and, with other university and industry laboratories, on the most effective means of active control. By using more complicated mathematics and developing more complex computer programs, the research groups are reducing the numbers of sensors and actuators necessary for control and improving the effectiveness of the systems.

—*Linda Shiner*

COURTESY ANN DOWLING, UNIVERSITY OF CAMBRIDGE

Researchers at the University of Cambridge in England analyzed a combustor's flame to detect instabilities.

2006

Now that GPS has found its way into the general aviation system, the next decade looks good for the integration of microprocessors into every genav nook and cranny. I foresee the retrofitting of today's fleet of old-tech airplanes with new-tech digital systems that will maximize what we already have in the way of airframes and powerplants.

It's my bet that the main engines for Cessnas and Beeches and Pipers in 2006 will still be traditional Lycomings and Continentals. But those engines will not be controlled by the pilot through the "dumb" throttle-prop-mixture panel controls we have today. Instead, a single lever will handle everything, since it will connect with a computer, which will use its many sensors (as computers do in today's automobile powertrains) to modify fuel flow, air intake, spark timing, and prop pitch to suit what the pilot wants to do. Every automobile engineer with whom I've spoken about the post-1987 leaps in fuel economy, emissions reductions, and raw performance of our cars has attributed the improvements to the integration of computers into every part of the car's anatomy.

—Steven L. Thompson, author, pilot, and automotive journalist

DARKSTAR UAV COURTESY ERIC SCHULZINGER/LOCKHEED MARTIN

2006 We have identified several technology areas crucial to achieving our vision for the 21st century: warfighter training, space technology, hypersonics, information dominance, crew escape, aging aircraft, high-cycle fatigue, and affordability. Among these areas some of our specific research projects target the following:

1. data fusion: correlating inputs from multiple sources and formats;
2. highly maneuverable aircraft: using three-dimensional thrust vectoring and vortex control to fly efficiently at very high angles of attack
3. advanced cockpits: combining advanced missiles with helmet-mounted systems to aim radars, weapons, and sensors;
4. standoff weapons/platforms: controlling future battlespaces with unmanned aerial vehicles and hypersonic missile systems;
5. directed energy: developing weapons from lasers;
6. smaller satellites: using standardized components and higher performance power systems for reliable, cheaper operations.

While such technological advances are important, I must stress that for the next decade, the number one trend affecting the realization of our vision is affordability. In 10 years it is possible that three generations of pilots will have flown our B-52s. As the aircraft in our fleet continue to age, we will be looking hard at the ways to extend operational service life.

—Sheila E. Widnall, Secretary, U.S. Air Force

Iridium's constellation of comsats

COURTESY IRIDIUM, INC.

2006 The aerospace industry has lost some 553,000 people, each of them representing a valuable skill developed over a period of years. We will lose more, through further industry adjustment and normal attrition.

When military production stabilizes and commercial aircraft manufacture reaches expected levels, how do we replace those lost skills? We're having a hard time enticing young people to consider aerospace as a career. Generally, they regard our industry as one that offers little in the way of career security and not much more in the way of occupational excitement.

This is not yet a problem since the industry's personnel needs are currently depressed. But industry leaders think it may be the biggest problem we will face a few years down the road.

—Don Fuqua, President, Aerospace Industries Association

2006 It used to be that space was reserved primarily for national security and science missions. In the next decade, satellites and other space-based technologies will play a much greater role in the day-to-day activities of more and more people. Systems now being designed will provide point-to-point fax, voice, and data communications to any point on the globe. Today, the Department of Agriculture uses satellite imaging to project crop yields. Tomorrow, farmers will use data from space assets for precision agriculture. They will be able to precisely determine what areas of a field to cultivate for maximum yield and how much to water and fertilize each section to maximize efficiency and minimize pollution.

—Norman R. Augustine, President, Lockheed Martin Corporation

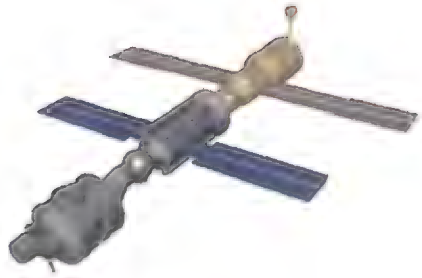
Finally, the Space Station

Over the course of 40 to 45 missions, flown predominantly by the U.S. space shuttle and Russia's launchers, NASA and its partners will assemble the international space station by early 2003. Current plans allot 34 missions to deliver 400 tons of station facilities and hardware and 10 missions to resupply the station or replace scientific payloads. Construction begins in November 1997 with the launch of the first module—a Russian-built, U.S.-bought Functional Cargo Block (FGB). The 21-ton spacecraft will provide electrical power, attitude control, communications, and propulsion for early assembly flights and will serve as a storage closet for crew supplies as well as a gas station. Tanks encircling the craft can hold 6.3 tons of rocket fuel.

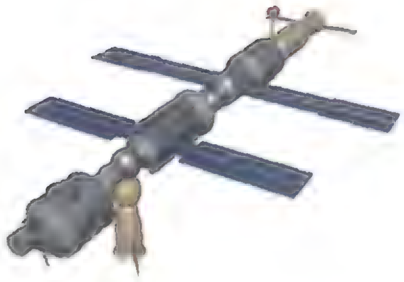
NASA is making minor adjustments to the assembly schedule to accommodate the needs of international partners; in January, for example, NASA and the Russian Space Agency negotiated an agreement replacing three Russian Zenit launches with one space shuttle launch to deliver the components of a Russian power platform. The change will delay other deliveries, but key elements in the construction plan have remained stable. By May 1998, the space station will be ready for three crew members to move in.

NOVEMBER 1997
The FGB has two forward docking ports and a third one aft.

DECEMBER 1997
The shuttle *Endeavour* delivers two docking assemblies and a U.S. module—Node 1—an elbow that has six more berthing ports for subsequent pressurized modules.

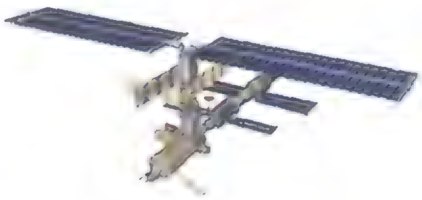


APRIL 1998
A Proton rocket delivers the Russian-built service module, a direct descendant of the Mir core module with living and work areas, sleeping compartments, toilets, and exercise equipment.



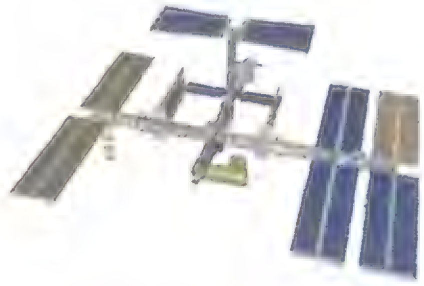
MAY 1998
A Soyuz TM crew transfer vehicle is installed at the nadir port of the FGB to ensure that an ill or injured crew member can get back to Earth. The station is now open for permanent occupancy.

JUNE 1998—OCTOBER 1998
Two U.S. missions deliver segments of the truss, solar arrays, a heat radiator, and a third docking assembly.

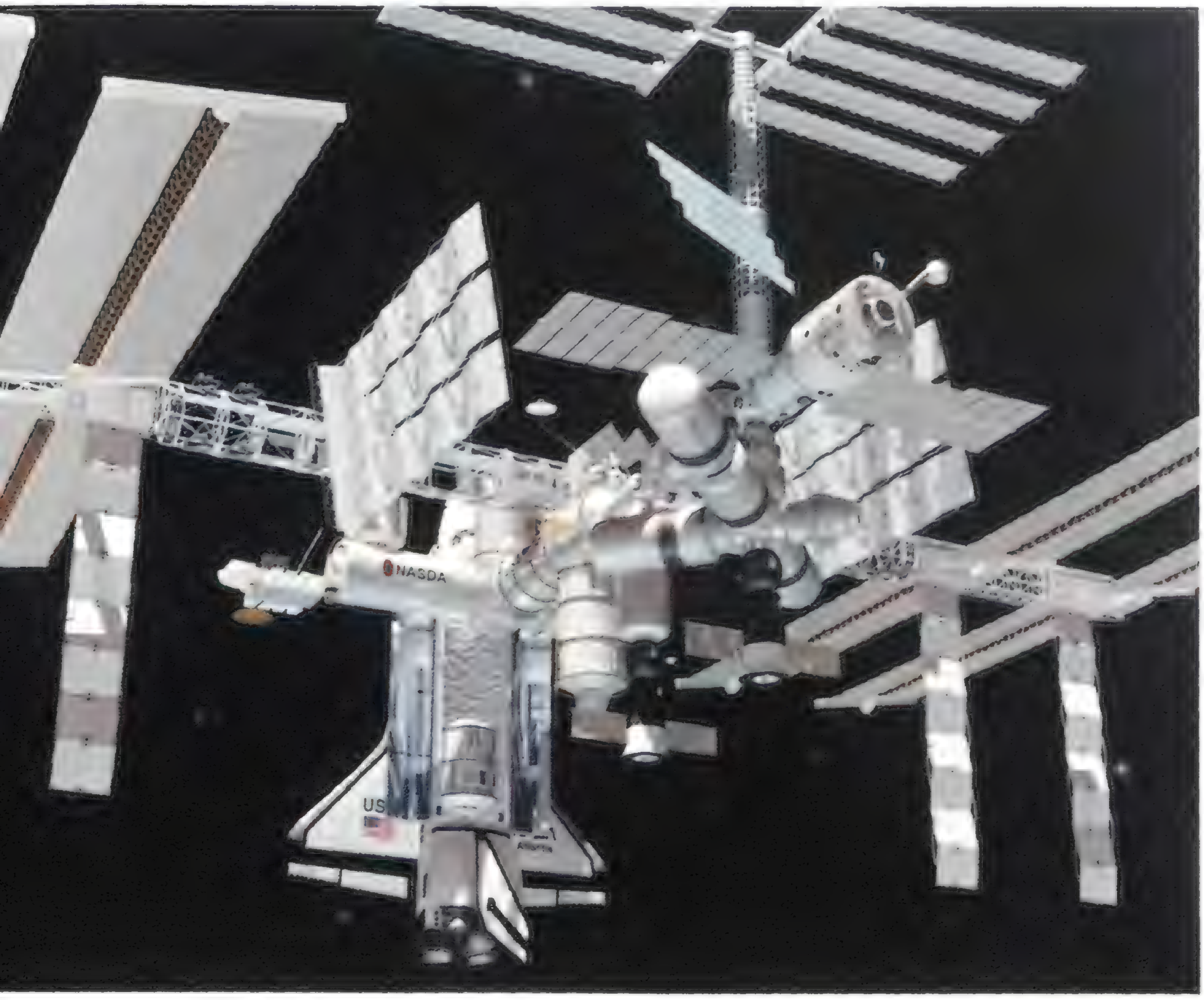


NOVEMBER 1998—APRIL 1999
Three U.S. missions add the U.S. laboratory and equipment, robotic manipulating arm, airlock, and radiators.

JUNE 1999—FEBRUARY 2000
Six U.S. missions deliver truss segments, radiators, solar arrays, U.S. Node 2, a cupola for viewing robotic assembly operations, and components of the Russian science power platform. A Russian mission delivers solar arrays and other hardware.



MARCH 2000—AUGUST 2000
The Japanese Experiment Module (possibly launched by an H-2 booster), logistics module, and remote manipulator arm are attached to the station. Two Russian missions deliver an airlock and universal docking module. A U.S. mission delivers a truss segment and solar arrays.



SPACE STATION ILLUSTRATIONS COURTESY NASA/JOHNSON

February 2001—early 2003
Four Russian missions add research and life support modules. Seven U.S. missions deliver the Japanese external facility, U.S. centrifuge, U.S. living quarters, truss segment and solar array, and a second crew return vehicle to complete U.S. assembly by June 2002. Two European Ariane 5s deliver supplies and equipment and, in early 2003, the European Space Agency's attached payload module.

For more about the future, browse the Web at: www.airspacemag.com/10th/2006.html

>SIGHTINGS<

To commemorate the 10th anniversary of this magazine, photographer and long-time *Air & Space/Smithsonian* contributor Chad Slattery set himself the Herculean task of creating the Roman numeral 10 entirely with aircraft. His first step was enlisting the participation of Mojave Airport manager Dan Sabovich, who volunteered the use of his facility. Most of the airplanes came from the airport, though several arrived in response to a call Slattery made to every segment of the Southern California aviation community.

Several days before the shoot, airport personnel staked out the X with nylon string. Slattery used scale silhouettes to determine positioning. Actual positioning took four hours. "Just when everything was ready, it began to rain," Slattery says. "Then it *really* started raining. Because many of the aircraft were available for a limited time, we did not have the option of waiting out the storm. We launched and began shooting." Leaning out of a Hughes 500 helicopter piloted by John Hagen at an altitude of 1,400 feet, Slattery used two cameras: a Nikon with a 105-mm lens and a Pentax with a 150-mm lens. Cameras and photographer were soon drenched.

After the rain and continuous buffeting against the helicopter had knocked both cameras out of commission, Slattery radioed to release the airplanes. "One hour later the sun broke out," he says. "Pilots reported a glorious flight home." (For the identities of the airplanes, see p. 103. For more about the shoot, browse the Web at www.airspacemag.com/10th/sightings.html)


204 S

Boeing's Big Gamble

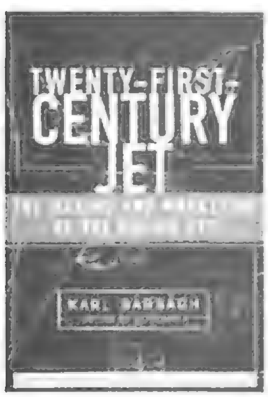
Twenty-First-Century Jet: The Making and Marketing of the Boeing 777 *by Karl Sabbagh. Scribner, 1996. 366 pp., $25 (hardcover).*

COURTESY BOEING

With the 777, Boeing aimed to take on Airbus in the twin-jet arena.

A protagonist drives this story but he remains offstage, unseen, never mentioned. Jean Pierson, the feisty chief executive of the European Airbus consortium, is the toughest competitor Boeing has ever faced. And when Boeing finally committed to developing the 777, it was to gain a place in a market that Airbus seemed to have preempted—that of the big twin, an airliner offering near-jumbo capacity but with the efficiency and economies of two jet engines rather than four.

As well told as this tale is, it completely lacks the competitive context. Airbus as a whole gets scant mention. Yet it wasn't until Airbus took a technological and marketing leap ahead of Boeing in developing new airframes that Boeing was forced to develop the 777 as a counterstroke to both the A330 and A340. At the same time, Airbus sideswiped Boeing with the A320, which highlighted the obsolescence of Boeing's 737 series. So what makes this book significant is the light it sheds on Boeing corporate caution. The technical leap from its last wholly original product, the 767, to the 777 was so fundamental that it required deep cultural changes in the company's Seattle headquarters.



Sabbagh does a good job documenting the outcome—the first Boeing designed entirely on computers, the adoption (with caveats) of fly-by-wire controls, the unprecedented pressure on the Federal Aviation Administration to grant the 777 early ETOPS (clearance to fly transoceanic routes on two engines). One reads with fascination as Phil Condit, the 777's main begetter, faces up to the ultimate Seattle virility test: betting the company on one airplane.

Condit turns out to be the embodiment of Boeing's new culture. As Airbus stole a substantial lead with the big twins, Boeing seemed afflicted by a managerial paralysis, though actually it was taking a calculated gamble. Boeing wanted to let Airbus freeze its metal, beyond change, and then do it better. Sabbagh recounts the ritual known as Dirty Pool, in which a plywood mockup of a new Boeing cabin is shown to the airlines and its virtues over the opposition are rammed home. In the case of the 777, the edge over the Airbus came down to bigger overhead bins, more headroom, and a significantly more capacious cabin. Not to mention at least 50 more bums on seats.

Boasting of its attention to the airlines' needs, Boeing sounds like a reformed drunk. Condit knew that the company had once been dominated by engineers who put the airplane first and the airlines second. With the 777 he set out to bring the two into balance. Having delivered on the cabin, they delivered on the skin. The aerodynamics, something Condit has in his bones, turned out to be better than his engineers promised. The 777 was so slippery that its cruise speed was upped from .83 Mach to .84; Boeing gleefully reminded the airlines that Airbus had fallen short on its drag promises.

Nonetheless, an air of self-congratulation does not permeate this account (which is the companion volume to a PBS television series). The old Boeing *zeitgeist* of collective memory and generational tension (not evoked by Sabbagh) made hubris unlikely. Every Boeing success (and the 777 is one) is constrained by the memory of painful Boeing failures. If Phil Condit doesn't sound smug as he sees Boeing winning back two-thirds of the world market for

commercial airliners and leaving Airbus with 15 percent, it's because he knows they're still out there. Pierson won't give him quarter. Now Condit, who will become Boeing's CEO on April 29, has to sell a new generation of 737s, as well as face up to the toughest call of all: how to replace the 747.

—Clive Irving is the author of Wide-Body: The Triumph of the 747 *(William Morrow & Co., 1993).*

Thread of the Silkworm *by Iris Chang. Basic Books, 1995. 329 pp., b&w photos, $27.50 (hardcover).*

It is one of the ironies of the cold war that the man who designed the DF-5, China's first intercontinental ballistic missile, was educated at MIT, taught at the California Institute of Technology, and for nearly a decade advised the U.S. Air Force on advanced weapons. In *Thread of the Silkworm* author Iris Chang provides a fascinating biography of the scientist in question, Tsien Hsue-shen, who in 1955 was deported to China following a protracted, confusing, and ultimately losing battle with U.S. immigration authorities.

Tsien's story is a saga worthy of Kafka, and it might be humorous were the outcome not so tragic—for both Tsien and for the country of which he was, briefly, a citizen. Accused of being a member of the Communist party in the early 1950s, Tsien decided to leave the United States, but at the last minute he was stopped by immigration agents, who may have mistaken logarithmic tables in his luggage for coded secrets. Thereafter choosing to stay in his adopted country in order to clear his name, Tsien fought deportation for five years, only to be finally ordered out of the country as part of a POW exchange at the end of the Korean war.

Unlike most deportees, Tsien had a ready outlet for his anger: As head of Communist China's rocket and missile program, he became a kind of Wernher von Braun in reverse—fleeing a democratic society, Tsien found fame and fulfillment in a totalitarian one. Possibly because of his experiences in the United States, Tsien underwent a transformation in China, from apolitical ascetic to fervent convert. At best, he became a willing apologist for the excesses of Mao's so-called Great Leap Forward; at worst, Tsien was an architect of that debacle, which cost 30 to 70 million lives from famine. His legacy includes not only the DF-5 but also the infamous Silkworm missile, which China continues to sell on the international arms market.

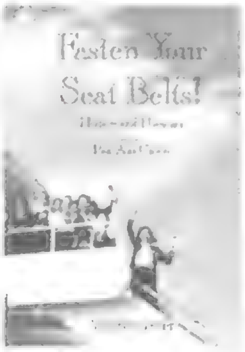
—Gregg Herken is chairman of the department of space history at the National Air and Space Museum.

Fasten Your Seat Belts! History and Heroism in the Pan Am Cabin *by Valerie Lester. Paladwr Press, 1995. 304 pp., b&w photos, $30 (hardcover).*

According to Pan American Airways' 1944 recruiting literature, the company's "ideal stewardess is blue-eyed, with brown hair, slender…weighs 115 lb., is 23 years old,…an expert swimmer, a high school graduate with business training—and attractive." Yet Pan Am had originally resisted the idea of female flight attendants, maintaining that the length and conditions of international flights were too strenuous. World War II manpower shortages forced a policy change, and by 1944 women with a wide range of impressive credentials—fluency in foreign languages, nursing and piloting qualifications, college degrees—were becoming stewardesses.

Valerie Lester, author of *Fasten Your Seat Belts! History and Heroism in the Pan Am Cabin*, herself worked as a Pan Am stewardess for 19 months in the 1960s, and was prompted by the 1991 demise of Pan Am to undertake a history of the airline's cabin crews. The result is not just a history of flight attendants but an engaging—although by no means rigorously historical—account of the evolution of air travel from the early days of the flying boat to the Jet Age. Pan Am was at the forefront of international aviation, and Lester's book is full of well-drawn witness-to-history anecdotes. President Franklin Roosevelt flew Pan Am to meet Winston Churchill at Casablanca, and Churchill was also once a Pan Am passenger. One harried stewardess even enlisted actor Montgomery Clift to help her prepare the cabin, mistaking him for a member of the flight crew.

Although Lester interviewed both male and female former flight attendants, the women's experiences form the book's core. In other industries women were employed on a temporary basis, but at Pan Am they quickly became a permanent commodity. Management had discovered that women added glamour to the skies; when Pan Am flew the first commercial around-the-world flight in 1947, much press coverage was devoted to the lone stewardess' cosmopolitan wardrobe.



The world may have been enthralled by the Pan Am girls, and the "girls" themselves may have had to fight off friendly passengers "with the six-inch hatpin that was part of our uniform," but Lester deftly attacks the stereotypes of sexual promiscuity that have long been

CD-ROMs

Carrier: Fortress at Sea, *interactive CD-ROM, Panasonic Interactive-Media Co., 3DO format, $59.95.*

If you own or can rent a 3DO player (3DO is the name of an electronic format used in CD-ROM compact discs and their players) and connect it to your home TV, you can interactively view much of the Discovery Channel documentary that lends its name to this game-*cum*-reference. Depending on where you roam through the hundreds of megs of content in this CD, you'll encounter text, still images, video, and sound.

Four "modules"—groups of content with tailored means to navigate within them—offer everything from the history of aircraft carriers to current footage shot (by Discovery) onboard the USS *Carl Vinson*, one of America's most modern nuclear supercarriers. A toolbar near the bottom of the video window provides various ways to access information. The 3DO controller resembles the current hand controllers for video games like Nintendo rather than the mouse control you may be used to in computer-based interactives.

A module called "Captain's Pass" allows the player to "roam" the *Vinson*'s various decks, but a far easier way to get the same information is to use the "index" function and progress alphabetically through the list. It makes about as much sense as the "tour."

There's also a simple flight "simulator" game based on an F-14 executing carrier landings. It has limited functions and is moderately entertaining for the roughly 15 minutes required to master it.

For those who want a quick introduction to aircraft carriers that approximates what you might find in a basic encyclopedia, but with the embellishments of motion, sound, and colorful video images, this CD-ROM delivers.

—George C. Larson is the editor of Air & Space/Smithsonian.

associated with stewardesses. Lester's only nod to the personal lives of her subjects is a brief chapter describing her own encounter with her future husband on a Pan Am flight, and her retirement from service to marry him. The flight attendants described in *Fasten Your Seat Belts!* are trained professionals who worked long hours, often under difficult conditions.

Lester makes no pretense of offering a comprehensive study of the role of women as flight attendants, or even of Pan Am itself. Although she has included a chapter about the development of the flight attendants' union at Pan Am, Lester barely scratches the surface of this topic. She also glosses over issues of discrimination, many of which persist in the airline industry today. Lester's Pan Am is filled with happy employees, and even the dissatisfied seem fiercely loyal.

But these topics can wait for another book. *Fasten Your Seat Belts* succeeds as the unapologetic story of a group of people who embarked on a great adventure, and Lester is at her best when she recalls the early, heady days of international flight, a time when the risks in new technology and the novelty of a shrinking planet combined to capture public attention.

—Jane Rosenzweig is a staff editor at the Atlantic Monthly.

Under the Guns of the Red Baron *by Norman Franks, Hal Giblin, and Nigel McCrery. Grub Street, 1995. 224 pp., b&w photos and color paintings, $35 (hardcover).*

For many people, World War I ace Manfred von Richthofen, better known as the Red Baron, remains the quintessential fighter pilot. Almost anything written about him since his somewhat controversial death nearly 80 years ago has added to his legend, that of a hunter and sportsman who reveled in the pursuit of his enemies. Richthofen's short 25-year life centers on 80 confirmed kills, but until now, rarely have the 123 men he downed between September 1916 and April 1918 been characterized in any detail.

After what must have been an exhausting search through official records (on both sides) and personal accounts, Norman Franks, Hal Giblin, and Nigel McCrery have done a remarkable job of telling the stories of those who went down "under the guns of the Red Baron."

Each kill, listed by date and number, is accompanied by Richthofen's official combat report, a recounting of the action, and a biography of each Allied airman downed. The authors have also found photographs of more than 100 of the victims, and artist Chris Thomas has painted 10 of the more memorable combat scenes.

The reader is quickly struck by the waste of war. These men went down in their prime, pulled away from dreams of youth to the horrors of war. We follow their lives from birth to death…and we get some surprises along the way. Some of the Baron's kills, it turns out, cannot be confirmed. Other victims are famous in their own right. For instance, number 1[illegible] from December 17, 1916, was James McCudden, a pilot who managed to escape (unknown to the Baron) and later shot down 58 German aircraft before being killed in a flying accident before the war's end.

The book is fascinating, particularly when read in concert with Peter Kilduff's recent definitive biography *Richthofen: Beyond the Legend of the Red Baron* (reviewed in *Air & Space/Smithsonian*'s

For an altogether different take on Manfred von Richthofen, check out *The Bloody Red Baron* by Kim Newman (Carroll & Graf, 1995, $21). A sequel to *Anno Dracula*, in which the bad count married Queen Victoria and turned Britain vampire-mad, this novel takes place during World War I, described as the first conflict fought with large numbers of vampires on both sides. One of them is the Red Baron, who commands a flying circus of vampires that can transform themselves into deadly flying creatures. Fighting against them are the vampires of Condor Squadron, which includes Albert Ball and James Bigglesworth. Newman takes this fantastic premise and makes it believable, helped by skillful writing that mixes sly humor with suspense and occasional gruesomeness. Readers should be alert to dozens of cameos by characters both real and fictitious, from Bulldog Drummond and Ernest Hemingway's Jake Barnes (in a chapter titled "The Moon Also Rises") to a vampiric Winston Churchill, who keeps a satchel of rabbits injected with Madeira for between-meal tippling.

—Tom Huntington is the managing editor of Air & Space/Smithsonian.

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Oct./Nov. 1994 issue). Kilduff, fluent in German, managed to tell a very personal story through original research. That so much new material could be found so long after the events is a testimony to the determination of good historians. The books together create the ultimate story of this legendary hunter of the sky.

—Jeffrey L. Ethell is the author of 56 books about aviation history.

In Brief

Spirit of Switzerland—With the Swiss Air Force Over Switzerland, *edited by Hansjörg Bürgi, Kurt Schaad, and Stefan Wunderlin. Aero Data Services, 1994 (Folchartstrasse 19, CH 9000, St. Gallen, Switzerland). 168 pp., color photos, $74 including air shipping (hardcover).*

The aircraft of the Swiss Air Force fly over some of the most picturesque—and peaceful—landscapes in the world. If you like your Dassault Mirage with a pinch of castle or a lake, this is the coffee table book for you. The photography, by the Swiss Air Force aerial surveillance team, is breathtaking, and text is in English, French, and German. The book does raise one question: What does a Swiss Air Force jet say when it's having its picture taken? "Cheese."

—George C. Larson

Hard Landing: The Epic Contest for Power and Profits That Plunged the Airlines into Chaos *by Thomas Petzinger, Jr. Times Books, 1995. 521 pp., b&w photos, $30 (hardcover).*

Another book about airline deregulation? Yes, and *Wall Street Journal* reporter Petzinger's tough look at the industry's last 25 years is a brutal portrait of its

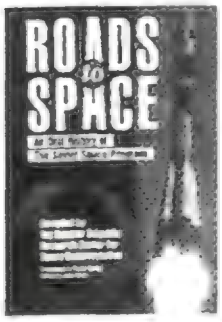
moral decline and fall. There are no real surprises in the cast of characters, and too few heroes. What makes this frank, matter-of-fact volume engaging is its detailed analysis of the politics and big-business duplicity

behind those happy flashy ads touting new routes and discount fares. We see all too clearly how petty grudges have driven a handful of men with boardroom-size egos (all of whom seem to cut their deals in steakhouses) to callously throw into turmoil the lives of thousands of employees caught in the middle.

So what's missing from this fine, thorough account? There's no look at how deregulation changed the lives of those workers. Nor are there such literary niceties as character development. We're given reams of fabulous detail (according to one pre-deregulation legal brief on the shipment of live animals, "For purposes of this case a rat is a bird"; in response to death threats, Eastern president Frank Borman starts wearing a bulletproof vest and packing heat). But Petzinger doesn't detail the change in, say, Frank Lorenzo's persona as he transforms from airline *wunderkind* to mogul to exile. What you do have is a straightforward telling of how the fat and complacent airline industry emerged from under regulation kicking and screaming, meekly mastered the competitive spirit, then overcompensated for its meekness by devouring everything in sight—including itself. The author is no poet, but he is thoroughly versed in his subject and its nuances.

—Phil Scott is the author of The Shoulders of Giants: A History of Human Flight to 1919 *(Addison-Wesley, 1995).*

Roads to Space: An Oral History of the Soviet Space Program, *edited by John Rhea, translated by Peter Berlin. McGraw-Hill, 1995. 513 pp., b&w photos, $49 (hardcover).*



Anyone who has ever struggled for hours on Christmas Eve with a gift labeled "some assembly required" can appreciate the difficulties and the rewards offered by *Roads to Space*, a raw collection of 34 independent accounts about the dawn of the Soviet space program. The contributions are almost random samplings of the long, wide flow of Soviet space history, with some topics overlooked and others triple-teamed by often grossly conflicting versions. But the space history buff with the endurance to wade through these richly textured and highly personalized fragments will find that the random threads are eventually woven into a magnificent tapestry of absolutely unprecedented vividness and color.

As the editors warn, this book, based on a collection of memoirs published in Russia a few years ago, is not for

reference, since it is full of misremembered dates, incomplete chronologies, plus the kind of rationalizations, excuses, and gossip typical of oral history. Nor is it for beginners: A good overall grasp of Soviet space history helps immensely. Few if any of the writers are household names, even in Russia, but they were key players in the space and missile industry, and they were devoted "space nuts," fully aware and deeply proud of their roles in opening the Space Age.

Editing was attempted by the American publishers, but without complete success. Names are often unreliable ("Patsayev" is spelled three different ways on two pages, and Alexander Nosov and Sasha Nosov are separately indexed as if they were different people). Key topics are unreliably indexed (the Plesetsk Cosmodrome has only one entry in the index even though it is mentioned half a dozen times, and I noticed similar oversights with highly interesting topics like the "Vulcan" super rocket and important figures such as Mikhail Ryazanskiy). And some topics aren't indexed at all (for example, a description of why the 1969 Soyuz-6/7/9 failed is described in one memoir, but never by name, so it isn't included).

Yet the material is a treasure. Countless incidents are told in vivid detail, with different versions providing unintentionally supportive and deeply humanized images. Three writers describe their most hated pests (all different) at the Kapustin Yar missile range in the late 1940s. The image of the joyously leaping dogs back from the first animal rocket flight is unforgettable. A detailed list of rocket accidents and the precise mistakes that led to them covers page after page of another engineer's memoir.

Historically fascinating and never-before-published facts abound. The biomedical telemetry from the dying Soyuz-11 cosmonauts is described, along with the results of their autopsies. The engineering judgment and organizational virtuosity of Sergey Korolyov is illustrated by dozens of examples. New details—some conflicting—emerge about the firing of live nuclear warheads on rockets in the late 1950s.

After all the effort of assembly, it's glistening jewels like these that make *Roads to Space* well worth the concentration it requires.

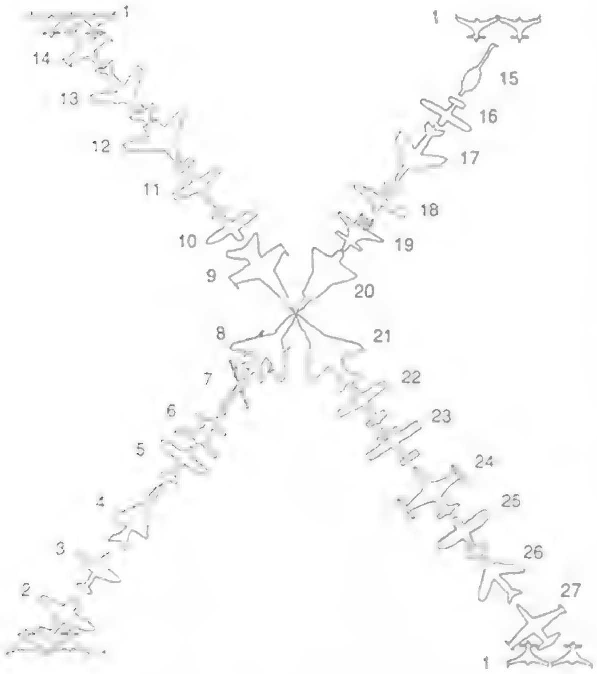
—A longtime observer of the Soviet and Russian space programs, James Oberg is the author of Red Star in Orbit *(Random House, 1981) and* Uncovering Soviet Disasters *(Random House, 1988).*

CREDITS

Aviation's Belle Epoque. Robert Wohl, a professor of European cultural history at the University of California in Los Angeles, is the author of *A Passion for Wings: Aviation and the Western Imagination, 1908–1918* (Yale University Press, 1994), which was reviewed in the Apr./May 1995 issue.

Across the Atlantic. By the time Henry Scammell went to work for Pan American at Idlewild airport in 1953, the era of the flying boat had ended. But he wrote about the *China Clipper* for our 1986 inaugural issue and again in 1989, and he has been looking back wistfully ever since. This is his 10th assignment for *Air & Space.*

Canadian artist Ken Dallison's paintings last appeared in *Air & Space/Smithsonian* in 1990, when he



Key to Sightings (p. 94-95): (1) Rutan Long-EZ, (2) Grumman F8F Bearcat, (3) Yakovlev Yak-3, (4) Mikoyan MiG-21, (5) Stinson 108-3, (6) Rutan Defiant, (7) Robinson R-44, (8) North American F-100C Super Sabre, (9) McDonnell Douglas F/A-18, (10) Howard DGA-15P, (11) Aermacchi M.B. 326 Impala, (12) North American S60 Sabreliner, (13) North American F-86E Sabre, (14) Morane-Saulnier MS-760 Paris, (15) Bell UH-1D Iroquois, (16) Cessna 150, (17) Hawker Hunter Mk.4, (18) Howard DGA-11, (19) Scaled Composites ARES, (20) Saab J35C Draken, (21) McDonnell F-4 Phantom II, (22) Cessna 206, (23) Beechcraft B76 Duchess, (24) Lockheed T-33, (25) Howard DGA-15P, (26) Mikoyan MiG-15, (27) Fouga C.M. 170 Magister.

CREDITS

illustrated a three-part series about the Battle of Britain.

B-36: Bomber at the Crossroads. Daniel Ford wrote about the last B-29 raid of World War II in the Aug./Sept. 1995 issue.

Illustrator John Batchelor specializes in military technology, and over the last 30 years he has produced thousands of color paintings, line drawings, and cutaways.

The Whole World's Watching. Tom Huntington is the managing editor of *Air & Space/Smithsonian*.

Computer illustrator David Peters is a frequent contributor.

The French Succession. William Triplett is a contributing editor. His last feature was "Dreams for Sale," a story about people who pay for the privilege of flying classic airplanes (Dec. 1994/Jan. 1995).

Richard Kalvar is a Paris-based photographer.

Rocket World. Frequent contributor Paul DiMare did the illustrations for "Life in the Egg," which appeared in the Oct./Nov. 1994 issue.

Out From the Shadow. James R. Chiles lives in Minnesota, where he works as an environmental planner. He has been writing on history, aviation, and technology since 1980. He received his pilot's license in 1976. For now, he satisfies his flying urge with simulators.

Based in West Los Angeles, Chad Slattery specializes in photography for the aerospace industry. He was the only photographer allowed unrestricted access to Thiokol during the 10th anniversary year of *Challenger*'s loss. He also conceived of and photographed the "X" for this issue's Sightings, p. 94.

Winged Warriors. Lance Thompson is a frequent contributor who writes about aviation, movies, and the West from his home in Sun Valley, California.

CALENDAR

April 13
Confederate Air Force Bluebonnet Airshow. Burnet, TX, (512) 756-2226.

April 13 & 14
Barnstormin' Business & Aviation Expo. Thomaston-Upson County Airport, Thomaston, GA, (706) 647-4500.

April 14–20
Sun 'n Fun '96 Fly-In and International Aviation Convention. Lakeland, FL, (941) 644-2431.

April 20
Aviation Career Day. Wilmington College, New Castle, DE, (302) 328-9401 ext. 133.

April 26–28
W&B Army Air Force Flying School Reunion. Chickasha, OK, (405) 224-5343.

April 28–May 3
83rd and 84th Air Depot Group Reunion. Imperial Palace, Las Vegas, NV, (713) 528-7480.

May 6–13
Confederate Air Force Group One Airshow. Gillespie Field, San Diego, CA, (619) 286-0160.

May 11 & 12
Shell Air and Sea Show: "A Salute to the U.S. Military." Ft. Lauderdale, FL, (305) 467-3555.

May 25 & 26
Memorial Day Weekend Salute to Veterans Airshow. Columbia Regional Airport, Columbia, MO, (314) 449-6520.

June 1
Great Northeast Swap Meet. Pick and choose among displays of aircraft parts, instruments, books, and clothing. South Jersey Regional Airport, Medford, NJ, (609) 267-4488.

June 1 & 2
London International Air Show. Performance by the USAF Thunderbirds. London, Ontario Airport, Canada, (519) 659-3298.

June 1 & 2
Mid-Atlantic Air Museum Sixth Annual World War II Commemorative Weekend. Mid-Atlantic Air Museum, Reading Regional Airport, Reading, PA, (610) 372-7333.

August 30
Reenactment of the 1929 Women's Air Derby. Be part of the 1996 Cleveland National Air Show by participating in the Ohio legs of this historic race. Deadline for entry: June 1. (216) 781-0747.

The Satellite Sky" Update/53

These regular updates to "The Satellite Sky" chart will enable readers to keep their charts up to date. Additions can be clipped and affixed to the chart at the appropriate altitude.

New launches

90 to 300 MILES

- KH-11 10 12-5-95 VAFB
- Progress M-30 12-18-95 TT
- Cosmos 2326 12-20-95 TT

300 to 630 MILES

- IRS-1C 12-28-95 TT
- Cosmos 2327 1-16-96 PL
- Skipper 12-28-95 TT
- XTE 12-30-95 CAC
- Titan 4 12-5-95 VAFB

6,200 to 13,700 MILES

- Cosmos 2323-25 12-14-95 TT

21,750 to 22,370 MILES

- Milstar 2 11-6-95 KSC
- Echostar 12-28-95 XI
- Gorizont 31 1-25-96 TT
- Koreasat 2 1-14-96 CAC
- Telecom 2C 12-6-95 KOU
- Insat 2C 12-6-95 KOU
- PanAmSat 3R 1-12-96 KOU
- Measat 1 1-12-96 KOU
- Galaxy 3R 12-15-95 CAC

Deletions

90 to 300 MILES

Cosmos 2305 down 12-19-95

Progress M-29 down 12-19-95

Inoperative but still in orbit

21,750 to 22,370 MILES

Cosmos 2133

Launched but not in orbit

90 to 300 MILES

STS-72 U.S. research	1-11-96	down 1-20-96
STS-75 U.S. research	2-22-96	down 3-9-96

FORECAST

In the Wings...

Minesweeper. It's not the Navy's most glamorous job, but the Sikorsky Sea Dragon helicopters that sweep for mines protect the fleet from unpleasant surprises at sea.

Splendors From Space. The Hubble Space Telescope continues to capture dazzling pictures of the Universe. Who gets to say what the Hubble sees?

The First To Fly. The memories of pilots whose certificates bear the signature of Wilbur or Orville Wright.

The Loneliness of the Long-Duration Astronaut. U.S. and Russian biologists have carefully studied the effects on the human body of long stays in microgravity. The Russians seem to understand more than the Americans about the effects on the soul.

Me and My Falco, Part IV. In which our kit builder goes to a birthday party and meets his airplane's maker.

The Lindbergh Crate. Most people looking at the shipping crate that held *The Spirit of St. Louis* on its return voyage would see a box. Larry Ross saw a shrine.

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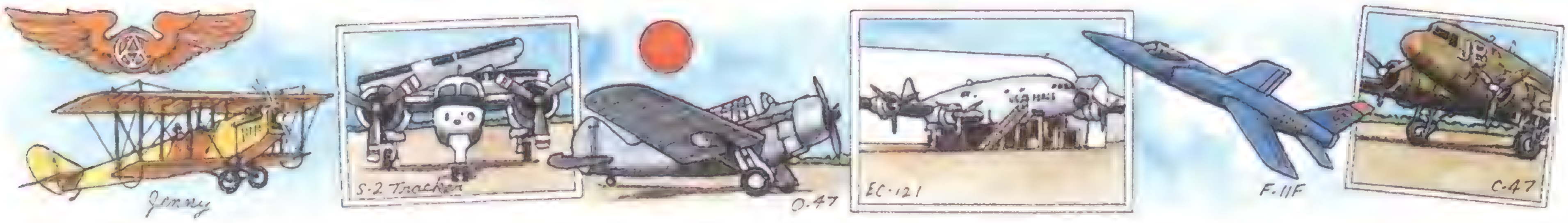

JOHN HEINLY

Winged Warriors

During World War II, Forbes Field in Topeka, Kansas, served as a staging base where bombers were given final modifications, matched with their crews, and sent overseas. One of the technicians there, Al Wilson, recalls designing a high-capacity ammunition box for gunners on B-24s. After Consolidated Aircraft checked out the design, Wilson says proudly, the company decided to make it a standard piece of B-24 equipment. Three decades later, Wilson and several veterans, pilots, and airplane enthusiasts founded the Combat Air Museum at Forbes to preserve the aviation history they helped make. In the same hangar where Wilson once worked, volunteers have built a collection of aircraft and related memorabilia from every war in which Americans flew.

Representing World War I air combat is a reproduction of a Curtiss Jenny trainer, donated by former barnstormer and Boeing test pilot Elton Rowley. Rowley spent seven years constructing the Jenny with his father-in-law, Ralph Austin, who once worked for Glenn Curtiss, designer of the real Jenny. Though they worked from original plans, Rowley and Austin made some changes in their version. "Jennies fell apart—they were stick and wire," Rowley says. For their frame, he and Austin used welded steel tube instead of wood.

The museum's World War II-era aircraft include a Meyers "Out to Win," or OTW, biplane. (Designer Al Meyers gave his airplane the nickname because he was determined to win the military's business with the trainer). The museum's OTW has a distinguished past: In addition to being the first off the production line, it co-starred with Clark Gable and Marilyn Monroe in the 1961 movie *The Misfits.*

The museum's rarest aircraft is the 1938 North American O-47, one of only three left. The airplane was designed with a window in its belly for observation and photo-reconnaissance, but it never got the chance to carry out those missions. In World War II those tasks were assigned to other kinds of aircraft, such as lightplanes, bombers, and camera-equipped fighters. The O-47 did serve in the war as a trainer and target towing craft.

World War II exhibits at the museum include a reproduction of the kind of German POW barracks where captured U.S. airmen were imprisoned. The museum's first curator, Gene Howerter, was guided in the construction by the reminiscences of museum members like Joe Higgins, a B-24 gunner who was one of 10,000 American prisoners in Stalag Luft 4 on the Baltic coast. Howerter wanted to make the display as authentic as possible. "Out of the old barracks they were tearing down at Forbes, we got World War II lumber and built bunk beds," he remembers. One member's wife stuffed burlap bags with straw and sewed them into mattresses. Higgins fashioned eating utensils, cups, and food trays out of cans, as his fellow prisoners had done. Other veterans who heard about the exhibit donated their own POW memorabilia and now conduct tours through the display during open houses.

Combat Air Museum, Forbes Field (by mail: PO Box 19142), Topeka, KS 66619. Phone (913) 862-3303. Open Mon.–Sat., 9 a.m.–4:30 p.m.; Sun., 10 a.m.–4:30 p.m. Adults $4, seniors $3.50, kids and visitors in military uniform $2.50.

One of the museum's most ambitious projects is a total reconstruction of a Fairchild UC-61, a sporty single-engine utility craft that the United States sent to England under the World War II lend-lease program. The UC-61 now being reconstructed had crashed in 1961, and the airline pilot who owned it donated it to the museum in 1990 on the condition that the staffers restore it to flying condition. Loyd Ellison, a Topeka machinist who has been involved with the museum since its inception, tackled the job. "Airplanes live longer if they're airworthy," he says. Visitors can walk through the shop where Ellison has been spending six days a week for the last four and a half years and watch the old airplane come back to life under the hands of a master craftsman. "If anyone comes in and wants to talk, I'll talk," he says. "That's what we're here for: so people can learn something."

To document military flying in the post-war period, the museum displays a Lockheed EC-121, a Constellation variant that the Air Force used for early-warning operations during the 1950s. Howerter had wanted an aircraft that visitors could walk through, and the EC-121, then in surplus storage at Davis-Monthan Air Force Base in Arizona, fit the bill.

Aircraft from the Korean war include the two that the Navy relied on most heavily—the Grumman F9F Panther fighter-bomber and the Douglas F3D Skynight night fighter—as well as a Republic F-84 Thunderstreak, a North American F-86H Sabre, and a Russian-built MiG-15. The post-Korea and Vietnam eras are represented by a McDonnell F-101 Voodoo penetration fighter, a Republic F-105 Thunderchief fighter-bomber, a McDonnell F-4 Phantom II, and a privately owned MiG-17.

The museum's Grumman F11F Tiger had flown with the Blue Angels from 1957 to 1968, and still bears the name of its last Blue Angel pilot—Hal Loney—beneath its canopy. The Tiger was deteriorating as an outdoor display at a nearby university when Howerter rescued it. His son Doug painstakingly re-created all the Blue Angels decals and instrument panel labels.

Last summer, a Delta Airlines pilot visited the museum and noticed that the Tiger had a damaged tire that would prevent it from being rolled out for an upcoming airshow. That night the visitor went back to his hotel, got on the phone, located a replacement tire, and arranged to buy it. It was installed in time for the airshow. The Delta pilot who made the donation was Hal Loney, the fighter's last pilot. Loney is pleased that his aircraft is in good hands once again.

—Lance Thompson

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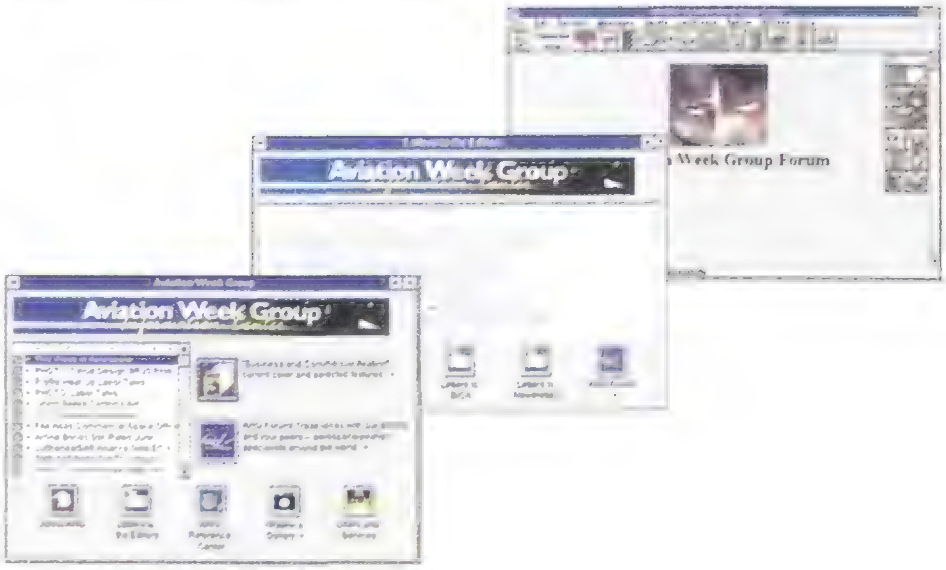

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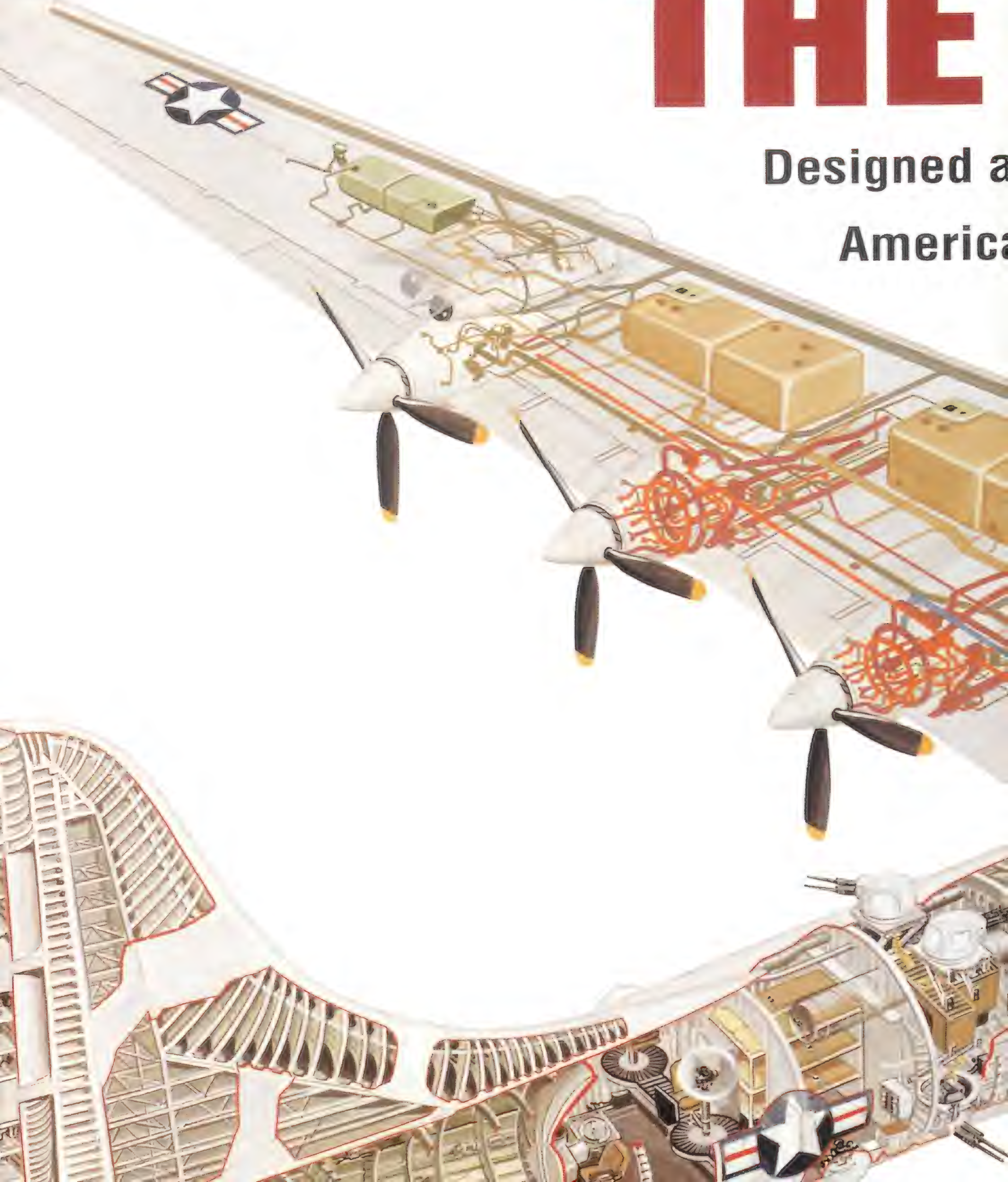
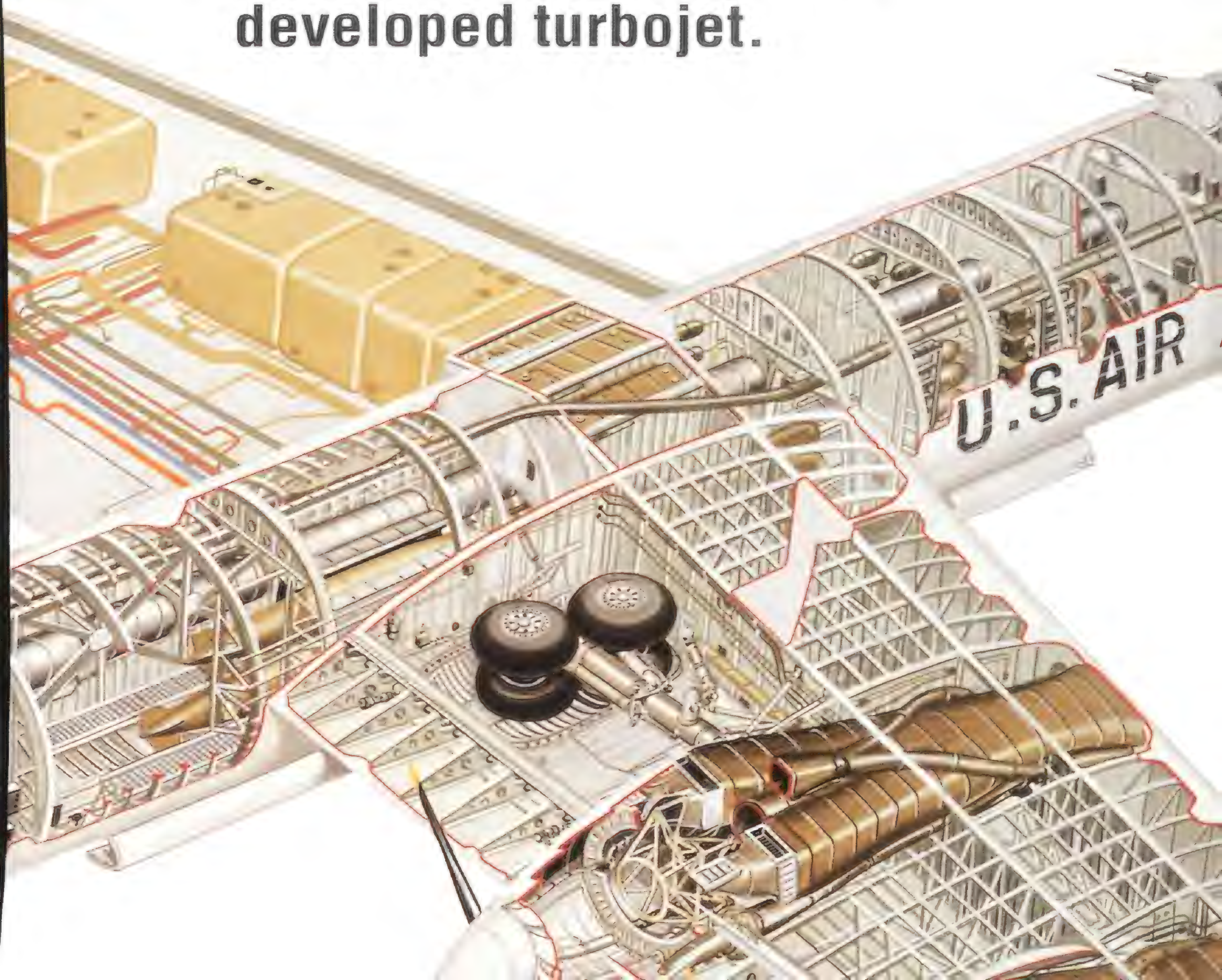


B-36D PEA

t the end of the piston-engine era, a's largest strategic bomber spent its career trying to outrun the newly developed turbojet.



CEMAKER

AIR&SPACE
Smithsonian

A supplement to the April/May
1996 issue of
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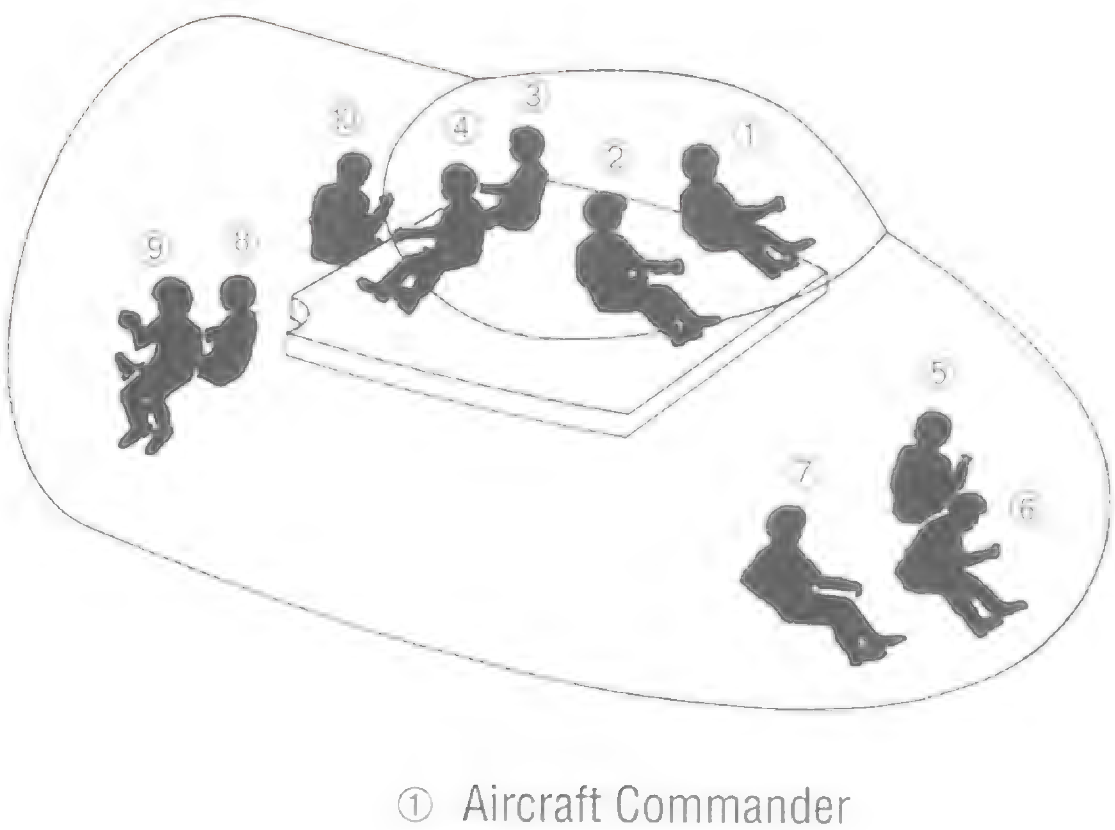
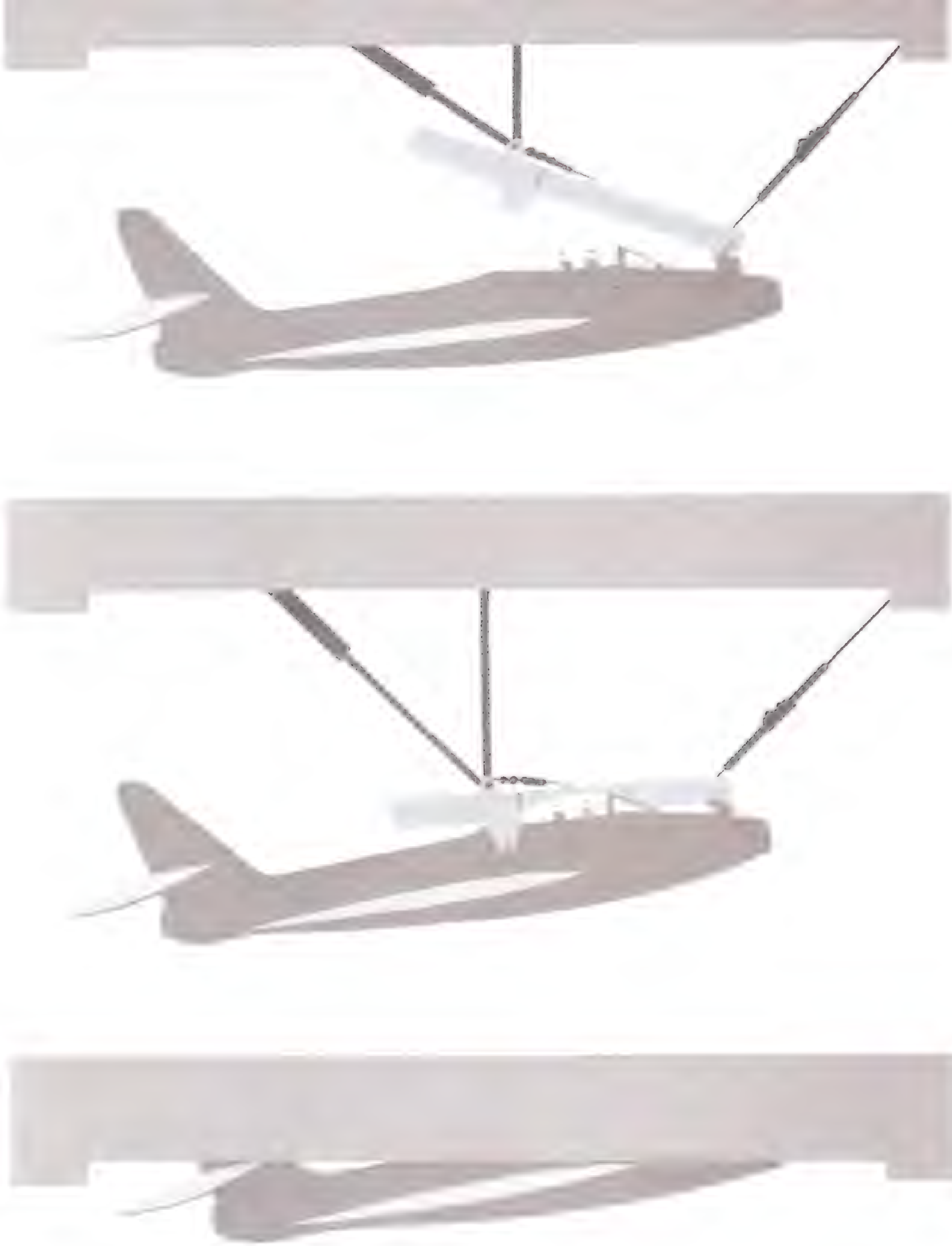


① Aircraft Commander
② Pilot
③ 2nd Flight Engineer
④ 1st Flight Engineer
⑤ Navigator



The FICON (Fighter Conveyor) Experiments

A series of tests in 1952 led to the development of a trapeze device that allowed the B-36 to carry, deploy, and retrieve a Republic F-84 Thunderstreak fighter (or an RF-84, the reconnaissance version). Aside from having hardware installed to engage the trapeze, the F-84 was modified so that the horizontal tail surfaces canted downward to clear the sides of the bomb bay in the retracted position. In actual operation, the fighter and bomber could take off individually. After they rendezvoused (assisted by electronic locating) and the fighter was taken aboard, the pilot entered the bomber via a catwalk. When the B-36 neared the target area, the fighter's pilot returned to his cockpit and deployed the F-84. Contracts were awarded to modify ten RB-36Ds and twenty-five RF-84Fs. Although the system was employed in actual operations for a brief period, midair refueling largely canceled the need for it, and it was phased out as the B-36D fleet was retired.

Engines: six 3,500-hp Pratt & W
four 5,010-lb.-thrust General Ele
Armament: Sixteen 20-mm M24
Crew: (normal) 15
Maximum weapons load: 72,000
Combat radius: 3,527 mi.
Maximum speed: 406 mph (at 3
Maximum altitude: 40,700 ft.
Length: 162 ft. Wingspan: 230 f

Sources: *All the World's Aircraft* (Jane's), *Pos*

Early turbojets were slow to respond to throttle input and required an interval of several seconds to spin up from idle thrust to maximum power. Carrier operations demand that an airplane's engines respond quickly and accelerate when a pilot elects to abort a landing. This was probably the main reason why the Navy opted for composite power in some aircraft during the late 1940s. The Ryan FR-1 (right) combined piston and turbojet power in a compact, high-speed fighter. The North American AJ-1 Savage (below) was designed to carry a nuclear weapon from a carrier deck and combined two large piston engines (similar to those on the B-36) with a turbojet mounted in its tail.

Composite

hitney R-4360-41 Wasp Majors;

ctric J47-GE-19s

A1 guns

lbs.

,200 ft.)

.

World War II Bombers (Office of Air Force History)

FR-1
Engines: one 1,350-hp Wright Cyclone R-1820-72W; one 1,600-lb.-thrust General Electric I-16

AJ-1
Engines: two 2,400-hp Pratt& Whitney R-2800-44Ws; one 4,600-lb.-thrust Allison J-33-A-10

Propulsion

Navigator

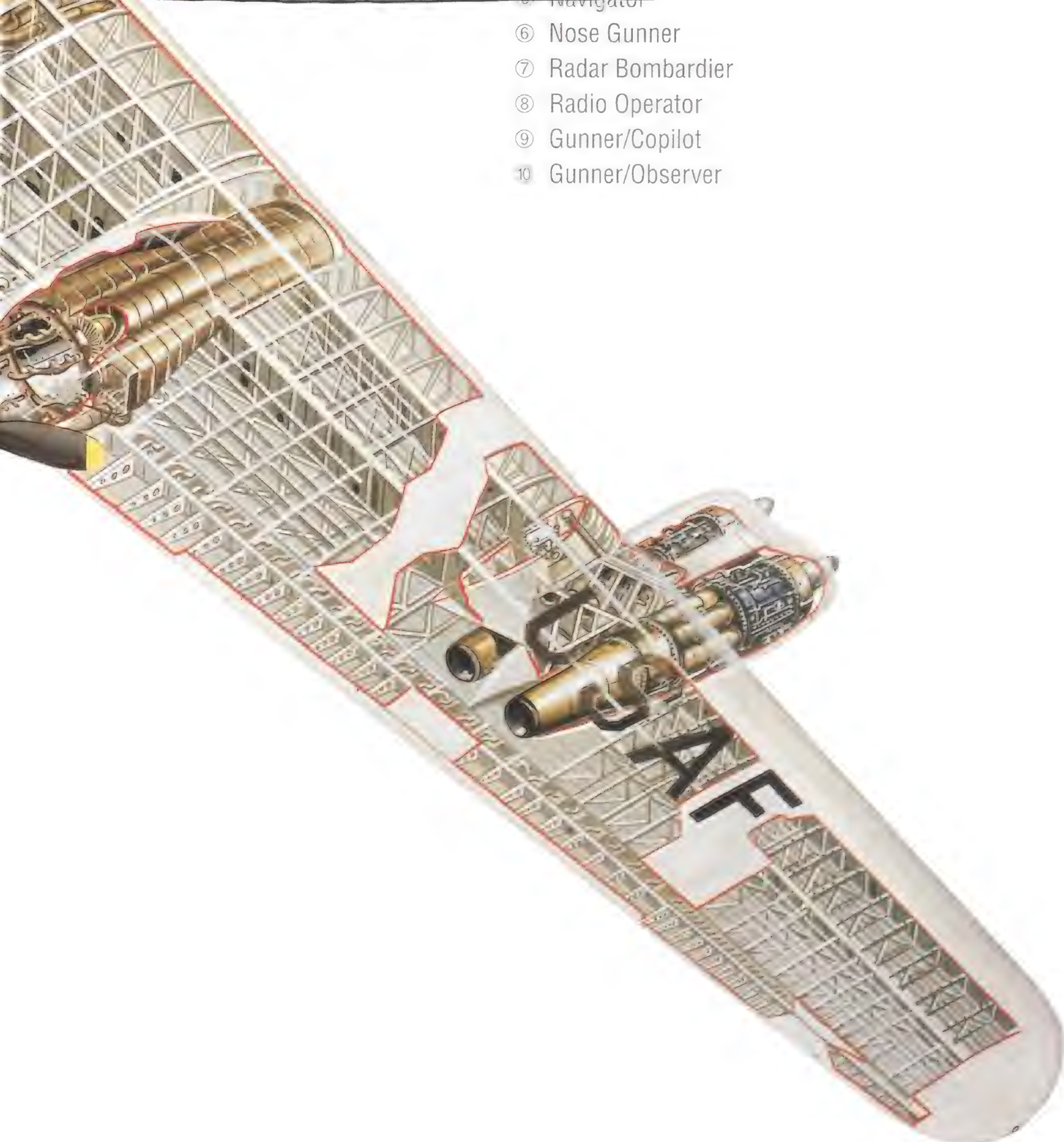
⑥ Nose Gunner

⑦ Radar Bombardier

⑧ Radio Operator

⑨ Gunner/Copilot

⑩ Gunner/Observer



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